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Review of White Hake (Urophycis tenuis) in the Northern Gulf of St. Lawrence in Support of a Recovery Potential Assessment

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed White Hake in Canadian waters, and based on a combination of genetic, behavioural (spawning locations and seasons), and meristic information suggested the existence of two populations (designatable units (DUs)). The definition of geographic boundaries between these two populations is complicated because of spatial overlap in their distribution. One population named the Southern Gulf of St. Lawrence (DU1) encompasses all of NAFO Div. 4T and the northern portion of Subdivision 4Vn. The second population identified as Atlantic and northern Gulf of St. Lawrence (DU2) includes the Scotian Shelf (NAFO Div. 4VWX), waters off southern and eastern Newfoundland, northern Gulf of St. Lawrence (NAFO Div. 4RS) as well as waters greater than 200 m in NAFO Div. 4T. The areas of overlap are: along the southern edge of the Laurentian Channel in NAFO Div. 4T at depths greater than 200 m and within NAFO Subdiv. 4Vn.

The Atlantic and northern Gulf of St. Lawrence population was designated as threatened in November of 2013. The reason provided by COSEWIC for this designation is:

- Adults in this population are estimated to have declined by approximately 70% over the past three generations. Most of this decline occurred before the mid-1990s. The population has remained fairly stable since then, and there has been little overall trend in area of occupancy. Restrictions on fisheries since the mid to late 1990s over most of their range may be responsible for stabilizing their numbers.

Following on the COSEWIC assessment, Fisheries and Oceans Canada (DFO) Science Branch was asked to undertake a Recovery Potential Assessment (RPA) for the White Hake populations assessed as threatened or endangered. This Research Document supports the RPA for the Atlantic and northern Gulf of St. Lawrence DU (ANGSL). It describes the current state of knowledge of White Hake in the northern Gulf of St. Lawrence (nGSL) portion of the ANGSL DU in terms of its biology, ecology, abundance, distribution and trends, habitat requirements and threats. Main sources of data were DFO and industry surveys, commercial landings, at-sea observer data, and stomach content databases. White Hake in the nGSL is not considered as a separate stock. There is no established directed fishery and it is not assessed under a regional peer review process. Limited information is available on White Hake in the nGSL. The species is broadly distributed in water depths between 175 and 350 meters, with concentrations along the slope of the channels of the nGSL. An index of abundance, based on data from the DFO RV summer survey, was developed for this RPA. This index, estimated for the 1985-2014 period, indicates that the abundance of White Hake in the nGSL declined rapidly from the mid 80s to early 90s, and has since remained at low levels. The information contained in this document may be used to support the development of recovery plans and decision-making with regard to the issue of permits, agreements and related conditions under the SARA.

Examen de la merluche blanche (*Urophycis tenuis*) dans le nord du golfe du Saint-Laurent en l'appui à l'évaluation du potentiel de rétablissement

RÉSUMÉ

Le Comité sur la situation des espèces en péril au Canada (COSEPAC) a évalué la merluche blanche dans les eaux canadiennes et a estimé qu'il y avait deux populations distinctes (unités désignables ou UD) à partir d'une combinaison de données génétiques, comportementales (lieux et saisons de reproduction) et méristiques. La définition des limites géographiques séparant les deux populations est complexe en raison du chevauchement spatial de leurs aires de répartition. La population du sud du golfe du Saint-Laurent (UD1) comprend la division 4T de l'Organisation des pêches de l'Atlantique Nord-Ouest (OPANO) et la partie septentrionale de la sous-division 4Vn. La deuxième population, dite de l'Atlantique et du nord du golfe du Saint-Laurent (UD2), comprend le plateau néo-écossais (division 4VWX de l'OPANO), les eaux au large du sud et de l'est de Terre-Neuve, le nord du golfe du Saint-Laurent (division 4RS de l'OPANO) ainsi que les eaux situées à plus de 200 m de la division 4T de l'OPANO. Les zones de chevauchement se situent à la pointe sud du chenal Laurentien dans la division 4T de l'OPANO, à des profondeurs supérieures à 200 m, et dans la subdivision 4Vn de l'OPANO.

La population de l'Atlantique et du nord du golfe du Saint-Laurent a été désignée comme étant menacée en novembre 2013. La raison donnée à cette désignation par le COSEPAC est :

- Les adultes de cette population ont connu un déclin estimé à environ 70 % au cours des trois dernières générations. La majeure partie du déclin s'est produite avant le milieu des années 1990. La population est demeurée assez stable depuis, et il y a eu peu de tendance générale dans la zone d'occupation. Les restrictions visant la pêche du milieu à la fin des années 1990 dans la majeure partie de l'aire de répartition sont peut-être responsables de la stabilisation des effectifs.

À la suite de l'évaluation du COSEPAC, il a été demandé à la Direction des sciences de Pêches et Océans Canada (MPO) de réaliser une évaluation du potentiel de rétablissement (EPR) des populations de merluche blanche considérées comme menacées et en voie de disparition. Le présent document de recherche appuie l'évaluation du potentiel de rétablissement de l'unité désignable de l'Atlantique et du nord du golfe du Saint-Laurent (ANGSL). Il décrit l'état actuel des connaissances sur la merluche blanche de l'UD ANGSL dans le nord du golfe du Saint-Laurent (NGSL), en ce qui concerne sa biologie, son écologie, son abondance, sa répartition et les tendances, ses besoins en habitat et les menaces qui pèsent sur elle. Les principales sources d'information sont les relevés de l'industrie et du MPO, les débarquements de la pêche commerciale, les données recueillies par le programme des observateurs en mer et les bases de données sur les contenus stomacaux. La merluche blanche du NGSL n'est pas considérée comme un stock distinct. La population n'est pas visée par une pêche dirigée établie et n'est pas évaluée dans le cadre d'un processus régional d'examen par les pairs. Peu de renseignements sont disponibles sur la merluche blanche dans le NGSL. L'aire de répartition de l'espèce s'étend de profondeurs allant de 175 à 350 mètres, avec des concentrations le long du talus des chenaux du nord du golfe du Saint-Laurent. Dans le cadre de la présente évaluation du potentiel de rétablissement, on a mis au point un indice d'abondance de la population, fondé sur les données obtenues pendant le relevé estival d'un navire de recherche du MPO. L'indice, fondé sur une estimation pour la période de 1985 à 2014, montre que la merluche blanche dans le NGSL a connu un déclin rapide à partir du milieu des années 1980 au début des années 1990. Elle se maintient depuis à des niveaux faibles. L'information contenue dans le document peut servir à l'élaboration de plans de rétablissement et à la prise de décisions sur la délivrance de permis, d'accords de conservation et leurs conditions, en vertu de la LEP.

SPECIES INFORMATION (COSEWIC 2013)

Scientific Name – *Urophycis tenuis*
Common Name – White Hake
Population: Atlantic and northern Gulf of St. Lawrence population
Current COSEWIC Status & Year of Designation – Designated Threatened in November 2013.

COSEWIC Reason for Designation – Adults in this population are estimated to have declined by approximately 70% over the past three generations. Most of this decline occurred before the mid-1990s. The population has remained fairly stable since then, and there has been little overall trend in area of occupancy. Restrictions on fisheries since the mid to late 1990s over most of their range may be responsible for stabilizing their numbers.

BACKGROUND INFORMATION

The Gulf of St. Lawrence is a semi-enclosed sea encompassing the North Atlantic Fishing Organization (NAFO) Divisions 4R, 4S, and 4T (Fig. 1). It is connected to the Atlantic Ocean through Cabot Strait to the southeast, and through the Strait of Belle Isle to the northeast. Most of the coastline, particularly on the north shore of Quebec is rocky, while the deep channels contain fine sediment (Loring and Nota 1973). Based mainly on recent genetic work (Roy et al. 2012), COSEWIC concluded that the Gulf of St. Lawrence hosts part of the two Designable Units (DU) of White Hake identified, including an area of spatial overlap between those DUs (Fig. 2). In the Gulf of St. Lawrence, the Southern Gulf of St. Lawrence White Hake population (DU1) occupies all of NAFO Div. 4T. Part of the Atlantic and northern Gulf of St. Lawrence population (DU2) occupies Divisions 4R and 4S as well as waters greater than 200 m in NAFO Div. 4T. This latter region of waters of depth greater than 200 m in Div. 4T is an area of spatial overlap between the two DUs in the Gulf.

DFO Science performed two distinct groundfish surveys in the Gulf of St. Lawrence (Fig. 3). The DFO Quebec region survey covers NAFO Divisions 4R and 4S, plus a portion of Division 4T that includes water deeper than 183 m (100 fathoms), as well as the St. Lawrence River Estuary. This survey is designed to sample the main habitat of the groundfish stocks under DFO Quebec Region mandate. The DFO Gulf Region survey covers the southern portion of the Gulf of St. Lawrence including most of Division 4T with the exception of the Estuary and waters deeper than 350 m. There is some overlap between Quebec and Gulf region survey strata in 4T Division comprising waters between 200 and 350 m (Fig. 3). In this review of the information of the Quebec region in support of an RPA of White Hake the information was treated to avoid duplication of data with the Gulf region. Hence, Div. 4T strata fully covered by both regions (QC 401,402, and 404) (Fig. 3) were excluded from the nGSL analyses. Quebec strata that were partially covered by Gulf region (403, 405, 406, 407 and 408) were reduced in area in the nGSL analyses to a surface that is only sampled by the Quebec region. This surveyed area is what will be referred to in this document as 4RST*. Figure 4 shows overall catches of White Hake during the August Quebec survey and indicates the area and catches that were not included in the nGSL analyses.

White Hake is the only commercial species of interest in the family of phycid hakes in the Gulf of St. Lawrence. Although a directed fishery was prosecuted in the southern portion of the Gulf, there has never been an established commercial fishery in the northern portion (i.e. Div. 4R and 4S) for this species. White Hake in Div. 4R and 4S is not considered as a managed stock and it is not assessed under a regional peer review process.

The biology of White Hake in the northern Gulf is not well-known. Fecundity and ageing are not performed on individuals from surveys, but a small number (about 10%) have been examined for maturity stages. No tagging program to study fish movements has been undertaken. As a result, information on age, fecundity, spawning, and migration are not available. For the purpose of this document, the size at maturity was set, as reported elsewhere, at 45 cm for male and female (e.g., Bundy and Simon 2005). Most of the information on biology, life history, distribution and trends in abundance were gathered through DFO and scientific surveys in the Quebec region. Information on the fishery is derived from ZIFF (Zonal Interchange File Format) files and observer databases. Stomach content databases were also reviewed for diet and predation topics.

BIOLOGY AND LIFE HISTORY PARAMETERS

BIOLOGICAL DATA

Biological data were not systematically collected during the early nGSL DFO surveys. However, since 1991, increasing efforts have been invested to collect more data. The sex ratio for White Hake in the August nGSL survey series is close to one (50.4% female). Length frequency distributions of catches indicate that White Hake range in size from 10 to 70 cm in the survey, peaking at 39 cm in 2014 (Fig. 5). The range of sizes for White Hake caught during the RV survey remained constant over the time series with no difference observed before and after the decrease in abundance (Fig. 6A).

Females reach larger size than males and constitute the majority of fish greater than 50 cm in length (Figs. 5A and 6B). Maturity has been visually assessed during the August survey in the last few years. These data indicate that females mature at a larger size than males, with 50% of the females reaching maturity at approximately 45 cm compared to 33 cm for males (Fig. 7).

In the absence of age determination, no information is available on the mean size at age, age at maturity and mortality of White Hake in the nGSL. Due to the timing of the August DFO survey, no data collection was feasible to determine the fecundity of mature females.

SPAWNING AND DISTRIBUTION OF EGGS AND LARVAL STAGES

Little is known about the time of spawning or the abundance of eggs and larvae for White Hake in the nGSL. White Hake spawning is suspected, but has not been confirmed, in particular for the northeast sectors.

Very few spawning male and female White Hake have been identified in the DFO August survey, suggesting that spawning would occur earlier in the year.

Eggs and larvae surveys have been performed at different periods and sectors in the Estuary and nGSL (de Lafontaine et al. 1984; de Lafontaine 1990; Bui et al. 2010; Grégoire et al. 2009; Grégoire et al. 2013). Due to the difficulties in identification, collected eggs of hake species are combined in the H4B group, which also includes fourbeard rockling and butterfish (Markle and Frost 1985). Surveys conducted in July 2004 and 2009 on the west coast of Newfoundland (Division 4R) found H4B group eggs and fourbeard rockling larvae principally around Port-au-Port Bay (Grégoire et al. 2009, Grégoire et al. 2013). In the northwestern Gulf around Anticosti Island (Division 4S), spring surveys (May and June, in 1985-1987, 2006-2007) collected H4B eggs, rockling eggs, and rockling larvae (Bui et al. 2010). The occurrence of eggs from June to August would agree with reported spawning time for White Hake. Hence, the reported spawning season for *U. tenuis* in the southwestern Gulf of St. Lawrence seems to cover the period of June to September, with mid-June (observed in 1966) appearing as the only obvious peak (Nepszy

1968). Other circumstantial evidence of spawning in the northeastern Gulf of St. Lawrence indicates some spawning occurs prior to May (Markle et al. 1982).

JUVENILE STAGE

Juveniles of White Hake (generally 10-30 cm in length) have been found during spring to fall seasons in eelgrass beds and at other inshore sites of the nGSL (Vladykov and Tremblay 1935; Lemieux and Michaud 1995; Nellis et al. 2012; Dutil et al. 2013) (Fig. 8).

DIET

Stomach content data are available for White Hake from a survey performed in 1954 (southern flank of Laurentian Channel, Gaspé Peninsula) near Rivière-au-Renard. Of the 61 hakes sampled, 47 had prey content consisting mostly of krill (*Meganyctiphanes norvegica*), along with some shrimp, amphipods (*Themisto* sp.), and fish (hagfish, herring, and barracudina) (Steele 1958). Crustaceans (krill and shrimp) and fish (herring) have also been reported as the primary prey of White Hake in other regions (Langton and Bowman 1980; Davis et al. 2004).

DISTRIBUTION ABUNDANCE AND TRENDS

SURVEYS

Two DFO bottom trawl groundfish surveys from the Quebec Region were examined as part of this review (Tables 1 and 2): a winter survey performed in January from 1978 to 1994, and a summer survey conducted in August from 1984 to 2014. These surveys have been designed to provide estimates of abundance for commercial groundfish species in the Estuary and nGSL. The sampling methodology follows a stratified random survey design, with stratification based on depth and geographic region (Bourdages et al. 2007).

In addition, two mobile gear surveys (Tables 1 and 2) put in place in 1994 through the Sentinel program were also examined for this review. These surveys follow a depth-stratified random survey plan and sampling methodology is similar to the DFO surveys (Fig. 3). However, the surveyed area does not include the Estuary strata (411, 412, and 413). These surveys consist of 300 stations randomly selected and sampled by commercial trawlers from Newfoundland and Quebec region (Sentinel surveys, SLGO.ca). Between 1995 and 2002, two mobile surveys were carried out annually in July and October. Since 2003, only the July survey remains.

GEOGRAPHIC DISTRIBUTION

Geographic distribution of White Hake in the nGSL is shown for the different mobile survey series (Figs. 9 to 12). These maps indicate that White Hake are present on average in 30% of the sets performed during these surveys. White Hake were usually captured along the 200 m isobath on the southern flank of the Laurentian Channel to the Gaspé Peninsula, and on the eastern flank of the Esquiman Channel near the southwest point of Newfoundland. White Hake were usually absent from depths less than 150 m, including the inshore west coast of Newfoundland up to the Strait of Belle Isle, and the lower shore of Quebec, north of Anticosti Island. Since 2011, there have been minor occurrences inshore at less than 100 m depth on the west coast of Newfoundland. The summer surveys suggest an expansion further into the Esquiman, Anticosti and Laurentian channels and in the Lower Estuary in the earlier years of the survey 1985-1991 (Fig. 10, 1985-1991). White Hake are less concentrated at the head of these channels in the recent years. The distribution maps also suggest the connectivity of White Hake in Divisions 4RS with those in adjacent areas, such as 3Pn in southwestern Newfoundland (Figs. 9, 11 and 12) and 4T along the Magdalen Shelf, into the Estuary.

Standardized catches (number per tow) subdivided into juveniles and adults indicate that these size groups are found at the same location in the nGSL.

Over the 4RST* survey area, key strata for White Hake abundance include strata 801 to 819 in Div. 4RS, with strata 403 and 405 in Div. 4T*. Highest catch numbers per tow were observed in the Southern Gulf of St. Lawrence strata 401, 402 and 404 that are excluded from the analyses (Figs. 3 and 13).

ABUNDANCE AND TRENDS

DFO winter survey – January 1978-1994

An annual winter survey was conducted in January with the *Gadus Atlantica* from 1978 to 1994 using an Engel 145 Hi-Lift trawl (no survey in 1982). The survey design included NAFO Divisions 4R, 4S, 3Pn, as well as strata deeper than 100 fathoms (approximately 200 m) in Division 4T, but excluded the Estuary (Tables 1 and 2, Fig. 3). The area surveyed was highly variable over the series (Fig. 9), mainly due to ice cover preventing fishing. The average area surveyed was 62,550 km^2 with the smallest area in 1992 amounting to 31,737 km^2 and the largest in 1980 with 100,400 km^2. Coverage of subdivision 3Pn and Division 4R was relatively consistent over the series, while coverage of Divisions 4T and 4S was more variable. Hence, the abundance indices are only presented for subdivision 3Pn (all strata) and for Division 4R (only strata consistently covered during the survey series) (Table 3; Fig. 14).

In 4R, mean number per tow varied between 2 and 6 fish from 1978 to 1986, decreased in 1987, and stayed low at an average of 0.4 fish per tow until the end of the series in 1994. In 3Pn, mean number per tow fluctuated between 1978 and 1987 with a maximum of 12.6 fish per tow in 1987. The abundance was quite stable during the last portion (1988-1994) of this series, averaging 4 fish per tow.

Length data for White Hake are available for the years 1985 to 1994. Average length of White Hake in 4R (42 cm) was significantly smaller than in 3Pn (52 cm) (Fig. 15).

DFO summer surveys – August 1984-2014

In the nGSL, the summer surveys have been conducted in August since 1984 (Table 1). For the period 1984-1990, the survey was completed by the *Lady Hammond* using a Western IIA trawl with a codend liner of 32/19 mm. From 1990 to 2003 and 2005 the survey was conducted by the CCGS *Alfred Needler* equipped with a URI 81'/114' (University of Rhode Island) shrimp trawl and a codend liner of 19 mm. Since 2004, the survey is carried out by the CCGS *Teleost* using a Campelen shrimp trawl with a codend liner of 12.7 mm. The vessels and trawls being considerably different, comparative fishing experiments were conducted in 1990 between the former two vessels, and again in 2004 and 2005 with the latter two, in order to estimate the catchability differences between the vessel/trawl pairs. The conclusion of those two comparative fishing experiments is that there is a significant catchability difference for White Hake between the Western IIA, the URI and the Campelen trawls, and that the difference is length dependent (Appendix 1; Bourdages et al. 2007). Figure 16 shows that Western IIA trawl would catch larger fish than the URI and Campelen shrimp trawls.

The results of these comparative fishing experiments were used to produce two summer survey series index of abundance: a *Lady Hammond*–Western IIA equivalent series and a *Teleost*–Campelen equivalent series. Only strata that have been consistently covered over the time series were included in the index of abundance. Hence NAFO subdivision 3Pn and strata added recently in the survey design are not included. Moreover, data for 1984 were excluded due to poor coverage of the surveyed area.

These series include strata from 4RS and part of 4T (identified as 4RST*), with some restrictions. To avoid duplication of data, deep strata (>200 m) in 4T that were covered by the southern Gulf survey were either removed when wholly overlapping (401, 402, and 404) or reduced in area (403, 405, 406, 407, and 408) in analyses. The excluded deep water strata 401, 402, and 404 are the most significant for captures of White Hake in the Quebec Region survey (Fig. 13) and are presented in selected comparisons, but not used in the calculation of the abundance indices. Missing year-stratum cells have been dealt with using a multiplicative model. Figure 17 shows the impact on the index of abundance of excluding the 4T* area.

Indices of abundance were produced for total White Hake as well as immature (< 45 cm) and mature (≥ 45 cm) size groups. The immature and mature indices begin in 1987 due to the absence of length data prior to that year.

The indices, in either Western IIA or in Campelen equivalent units, show that White Hake abundance was highest at the beginning of the time series (1985-1990), and rapidly declined to a low level in 1993. From 1994 to 2014, the abundance has remained low. Similar trends are observed for total, mature and immature size groups (Tables 4 and 5; Fig. 18).

Although the trend in abundance for total, mature, and immature populations are similar between the Western IIA and Campelen equivalent series, the ratio in abundances of immature and mature size groups is different because of differences in gear selectivity (Fig. 16). This is evident when looking at the proportions of immature (< 45 cm) and mature fish (≥ 45 cm) for the two indices (Fig.18). In the *Lady Hammond*-Western IIA series, there tended to be an equal amount of mature and immature fish (Fig. 18A), while for the *Teleost*-Campelen equivalent series, the indices indicate that more immature than mature fish were caught (Fig. 18B).

Since the current nGSL groundfish survey is performed with the *Teleost*-Campelen tandem, we favor using the values given by this series to estimate the actual White Hake population. The exercise of producing a Western IIA equivalent series was undertaken to allow a comparison with other regions that still use the Western IIA trawl for their groundfish survey. Hence, in 2014 the index of trawlable abundance for White Hake gives a total population of around 8.9 million individuals, of which 1.6 million would be mature fish (Table 5).

Sentinel program – mobile surveys

Two mobile surveys performed through the Sentinel program in the nGSL were examined for this review. Data for abundance and trends are reported only for the July survey which has the longest time series, 1995-2014. The indices of abundance presented are restricted to the northern Gulf 4RS and subdivision 3Pn. Data for Div. 4T are not presented.

From 1995 to 2004, the July index mean number per tow in 4RS fluctuated from about 0.4 to 2 fish (Fig. 19A; Table 6). Since then, with the exception of 2010, the July index has stabilized at low values (<0.5 fish per tow), below the average for the series. In 3Pn, the abundance index varied between 0.7 and 5 fish per tow during the 1995-2006 period and between 0.6 and 1 fish per tow, with the exception of 2010, in the last portion of the series (Fig. 19 B).

AREA OCCUPIED

The area occupied by White Hake was calculated from the August DFO RV trawl survey (1985-2014) catches using a Design-Weighted Area Occupied (DWAO) index. These analyses were based on strata that were consistently surveyed over the series. The area occupied by the total White Hake population was maximal between 1985 and 1991 averaging 47,500 km^2 and decreased thereafter, averaging 27,000 km^2 for the period 1992-2014. Similar trends were seen for mature and immature size groups (Fig. 20).

DECLINE

Decline was estimated using data from the two series of summer DFO surveys. Decline is based on a linear regression through the log-transformed abundance index over the years. Percent declines were calculated as $100*(1-\exp(b*\Delta t))$, where Δt refers to the change in time (years) and b the slope of the linear regression of the natural log of the population size plotted against year. Percent declines were calculated for the total, mature and immature size groups.

Decline was estimated for the two August survey series (Table 7; Fig. 21). Decreases of 80% and 82% in the total abundance between 1985 and 2014 were observed for the *Lady Hammond*-Western IIA and *Teleost*-Campelen series, respectively. Corresponding decreases in the abundance of the mature size group between 1987 and 2014 were 72% and 71% (Table 7). The decline in abundance is largely associated with the higher abundances observed between 1985 and 1991. Since 1994, the abundance of White Hake appears to be stable.

HABITAT AND RESIDENCE REQUIREMENTS

HABITAT

Cumulative frequency plots of White Hake catches in relation to depth, temperature, salinity and oxygen concentrations indicate that larger catches were more frequent over a narrow range of conditions, at higher values than the survey average, for depth, temperature and salinity (Fig. 22). On the other hand, larger catches of White Hake were observed at oxygen saturation levels lower than the survey average.

Depth

Over 90% of White Hake were found at depths ranging from 175 to 375 m, with the mean number per tow peaking at 250-300 m (Figs. 22 and 23). Moreover, there were no indications of differences in depth distribution between mature (≥ 45 cm) and immature (< 45 cm) size groups of White Hake.

White Hake catches by depth for the months of January, July, August, and October surveys also suggest that White Hake are found at similar depth range during those months, but could be more concentrated in deeper waters in January than in July and August (Fig. 24). However, data are not totally comparable, with the January (DFO) survey covering 1978-1994, while the July, August, and October surveys were analyzed for the 1995-2002 period.

Temperature

White Hake were most often caught on tows with near-bottom temperatures of 4-7°C, peaking at 5-6°C (Fig. 22). Catches in Div. 4RS were observed in warmer waters (5-6°C) than in Div. 4T, along the Laurentian Channel and into the Lower Estuary (4.5-5°C) (Fig. 25). Elsewhere, White Hake are reported to prefer temperatures of 6-11°C (Chang et al. 1999).

Dissolved Oxygen

Near-bottom oxygen saturation in the Gulf of St. Lawrence varies widely, from hypoxic conditions (generally < 30%) in the head of channels to near saturation in cold shelf areas (Fig. 26). From the August surveys, most tows with White Hake were characterized by mildly hypoxic levels at 100-150 µmol/l (~ 30-50% saturation) at depths of about 200-400 m (Figs. 22 and 27).

Hypoxia in the channels of the northern Gulf is believed to have worsened, then stabilized by the 1980s (Gilbert et al. 2005). While the presence of hypoxic conditions in the Estuary may be tolerated by some species such as Greenland Halibut (turbot), the tolerance of White Hake to low oxygen concentrations levels has not been estimated.

Salinity

White Hake was observed within a narrow range of salinities. Most of the catches occurred between salinities of 34 and 35 (Figs. 22 and 28).

Megahabitat groups

An atlas has been developed combining several data sources and surveys and interpolating a number of environmental variables including depth, slope, sediment type, salinity, oxygen, and temperature over a 10x10 km spatial grid of cells across the Gulf of St. Lawrence (Dutil et al. 2011). A cluster analysis performed on these variables classified the area into a series of benthic megahabitat groupings. Captures of White Hake during summer surveys were examined for their association with these megahabitat groupings based on the published shape files for the benthic grid of the St. Lawrence.

For the August RV survey, the largest mean catches of White Hake were found in areas corresponding to the deepwater megahabitats in the St. Lawrence atlas (Dutil et al. 2011) (Fig. 29). Megahabitat A (channel bottoms) covered two-thirds of deepwater areas and had over three-quarters of the tows with White Hake. The deepwater slope habitats B, C, D together covered half the area of habitat A, had only 17% of the tows with White Hake, but had higher mean catches (Fig. 30).

Overall, White Hake in the nGSL prefer deepwater slope habitats which have a relatively restricted spatial extent in the Gulf, particularly in comparison to the greater availability of the channel bottom habitat type.

Eelgrass bed and inshore coastal waters

Eelgrass beds are thought to be important habitats for demersal juveniles (Fahay and Able 1989), and McAllister (1960) described sand-hiding behaviour in young White Hake (76-102 mm long) in depths of about one meter off Prince Edward Island.

Between 2005 to 2013, a monitoring program sampled eelgrass beds in spring and fall seasons along the shores of the Estuary and northern Gulf, excluding Newfoundland (Fig. 8). Sampling depth ranged from 0 to 3 m. Immature Hake ranging from 52 to 260 mm (average 117 mm) were collected at 9 of 11 sites. No individuals were found at Rimouski (Estuary) and Old Harry Bay (Magdalen Islands). Because of uncertainty when identifying immature specimens, several species were recorded in databases to the level of genus (Nellis et al. 2012; Dutil et al. 2013). All specimens of *Urophycis* are assumed to be of *U. tenuis*. White Hake were more frequently captured during September, using fyke nets, at sites in Gaspésie (Penouille and St. Jean River, Div. 4T) and on the North Shore (Sept-Îles and Mingan, Div. 4S). Temperature at sites with White Hake ranged from 8 to 18°C, and salinity (when recorded) ranged from 11 to 16.

On the west coast of Newfoundland, sampling was conducted in shallow coastal waters in Bonne Bay during June from 2002 to 2009 using beach seines, gillnets, and a bottom trawl. From three sites over the eight-year period, a total of 21 specimens of White Hake ranging in length from 5 to 20 cm were captured (Currie et al. 2009; Bruce et al. 2010).

The specimens collected at inshore sites throughout the nGSL suggest that other northern sites might be habitats for young-of-the-year (YOY) immatures if surveyed.

CONCEPT OF RESIDENCE FOR WHITE HAKE

Species at Risk Act (SARA) defines "residence" as:

> "a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating" (s.2(1)).

White Hake do not have any known dwelling-place similar to a den or nest during any part of their life cycle therefore, in accordance to the DFO June 2013 policy statement on the "Application of Species at Risk Act Section 33 (Residence) to Aquatic Species at Risk" the concept of residence does not apply to White Hake.

THREATS AND LIMITING FACTORS

HABITAT

Habitat types

Inshore sites including eelgrass beds appear to be used by immature White Hake. The availability of shoreline habitats for young-of-year fish is not suspected to be limiting, although monitoring of shore sites is very limited and thus their importance remains unknown.

White Hake in the nGSL are found preferentially near slopes along deep channels with fine sediment. Such habitat types represent a relatively small area in the region. Their loss or degradation may represent a threat for the species.

Water conditions

Near-bottom temperatures on tows with White Hake catches appear to have increased slightly in recent years, but are within the preferred range of White Hake and unlikely to be a direct threat.

Dissolved oxygen levels appear to be low (hypoxic) in some deep habitat areas, in particular the Laurentian Channel in the Estuary, northwest of Anticosti Island, and east of Anticosti (head of Anticosti Channel). The impact of hypoxia is unclear for White Hake, but may be associated with avoidance if tolerance to low oxygen levels is similar to other codfishes, and unlike Greenland Halibut (turbot) and redfishes that were found in these deepwater areas, possibly tolerating the conditions.

Pollution

Chemical pollution from industrial and agricultural activities has been a longstanding concern for the ecosystems in the Estuary portion of the northern Gulf, particularly for large resident predators such as beluga whales and seals (Plourde et al. 2014). However, the Estuary appears to represent a marginal habitat for White Hake, with only a minor presence of the species in recent years. The role of chemical pollution in the Estuary on habitat quality for White Hake is unknown.

Of potential future concern is the exploratory offshore drilling being planned for oil and gas in the Old Harry site in the Laurentian Channel. The drill licence areas lie in between the areas of the largest remaining catches of White Hake in the nGSL, on the slopes of the channel to the southwest (primarily 4T DFO RV survey strata 401 and 404) and to the coasts of Newfoundland (Fig. 31). Preliminary numerical simulations were performed to determine the trajectory of a

potential oil spill at Old Harry (Bourgault et al. 2014). These simulations indicate that the spill may preferentially follow two main paths; one path northward along the French Shore of Newfoundland, and the second along the main axis of the Laurentian Channel. These preliminary results provide guidance for future more in-depth and complete multidisciplinary studies to address the impact of a possible oil spill at Old Harry in the Gulf of St. Lawrence.

Connectivity

A large marine protected area/conservation zone is proposed for the Laurentian Channel south of the Gulf of Lawrence in Newfoundland Region (Figure 32). Part of the benefits of such a reserve would be to protect habitat for White Hake (DFO 2011). Genetic studies have suggested that exchange between individuals takes place between the west coast of Newfoundland and Scotian Shelf, which could benefit from a conservation zone in the channel (Roy et al. 2012) (Fig. 33). Future exploration (seismic or acoustic surveys) and petroleum extraction may represent an unknown risk to this connectivity for White Hake between the Laurentian Channel area and the northern Gulf unit.

FISHERY

Commercial fishery

Reported landings data for Divisions 4R and 4S were extracted from NAFO 21B files for the period 1960-1990 and from ZIFF files (Zonal Interchange File Format) for the period 1991-2014.

White Hake in Divisions 4RS has never supported a major fishery. Since 1960, most of the landings were reported as bycatch in other fisheries (Table 8; Fig. 34). There has been some directed fishery according to the Quebec statistical database. However, this fishery was never managed under a quota. Reported landings increased from 46 t in 1960, peaking at 454 t in 1982. Annual landings averaged 137 t in the period 1960-1993. With reduction in fishing effort after the first moratorium on groundfish in 1994, annual landings averaged 11 t between 1997-2014 (8 t in 4R and 3 t in 4S). During that period, reported landings were as bycatch from the Atlantic Halibut, Cod, Redfish, and Greenland Halibut fisheries (Fig. 35). White Hake was caught mainly by longline (56%), gillnet (19%), and otter trawl (17%). For the recent period 2009-2013, White Hake was caught mainly by gillnet followed by longline (Table 9). Overall, catches of White Hake in Divisions 4RS were low. Bycatches from other fisheries were located mostly in Division 4R, on the west coast of Newfoundland, in St. George's Bay and along the 200 m isobath up the Esquiman Channel (Fig. 36).

Reported bycatches of White Hake were also examined using the at-sea observer database for the period 1990-2010. This database confirmed that White Hake bycatches are mostly from Redfish, Cod, Atlantic Halibut and Greenland Halibut. The proportion of bycatch rejected at sea ranged from 2 to 19% in those fisheries.

Bycatch in the shrimp fishery

Bycatch of White Hake in the Gulf of St. Lawrence shrimp fishery (4RST) has been investigated from the observer database (Savard 2013; Savard et al. 2013; Bourdages and Marquis 2014). White Hake between 20 and 26 cm is taken as bycatch in 7% of the shrimp fishing activities. For most sets, the catches are minimal (1 or 2 kg), discarded at sea, and not reported in the official statistics (Fig. 37). These bycatches are estimated to average 0.7 tonne annually (Table 10). Overall, this unreported bycatch is estimated to be less than 1% of the trawlable biomass estimates for White Hake in the Gulf of St. Lawrence for fish of less than 30 cm.

Estimated mortality rates

Relative *F* was calculated in the nGSL as the reported annual landings of White Hake divided by the annual estimated minimum trawlable biomass of the mature component of the population as derived from the DFO RV survey (Fig. 38). Average relative *F* in a pre-groundfish moratorium (1987-1993) period was estimated to 0.051, and this value decreased to an average of 0.007 in the post moratorium (1997-2002, 2004-2014) period.

PREDATION

Fish

A fish stomach content database from Quebec Region was examined to assess predation on White Hake in the nGSL. Atlantic Cod, Greenland Halibut (turbot), and Atlantic Halibut were fish species assumed to be large enough to prey on White Hake. Turbot had hakes (*Urophycis* spp.) identified in less than 0.03% (0.33% of prey contents by mass) of the stomachs analyzed between 1993 and 2009 (n=13,717) (Bernier and Chabot 2013). White Hake was found in only one of 490 Atlantic Halibut stomachs, and absent in all of the 17,387 Cod stomachs analyzed.

Seals

A study by Hammill and Stenson (2000) estimated that in 1996 total consumption of White Hake by harp, hooded, grey, and harbour seals in NAFO Divisions 4RS represented 0.1% (by weight) of the seal diet, equivalent to 642 t of White Hake. A subsequent paper by Hammill et al. (2007) reported on grey seal diet from samples collected between 1984 and 2004 in 4S (Anticosti Island, n=183) and 4R (west coast of Newfoundland, n=78). The Anticosti stomachs had a frequency of occurrence of 2.9% for White Hake, while none were identified in the Newfoundland samples. However, overwintering seals sampled near the Laurentian Channel (Cape Breton/Cabot Strait area) area did show more important predation rates, particularly for hake ranging in size from 25 to 60 cm (Hammill et al. 2014b).

Predation pressure by grey seals may be expected to rise with increasing numbers of seals. Population estimates of grey seals in the Gulf show continued growth (Hammill et al. 2014a), from 50,000 since the late 1990s to 100,000 in 2014. As a consequence, predation pressure on nGSL White Hake could potentially increase in the future.

RECOVERY TARGETS

BIOMASS RECOVERY TARGET

The abundance recovery target for the 4RS management area corresponds to a sustained increase in adult biomass at or above 40% of B_{MSY}. This target could be considered as the limit reference point (LRP) under the precautionary approach framework. A B_{MSY} proxy (9,016 t) was calculated as the average of annual mature trawlable biomass of the DFO RV survey for a productive period, here defined as 1987-1990. This period corresponds to a time of high mature biomass prior to the large decline noted after 1990 (Fig. 39). White Hake mature biomass has been below the 40% B_{MSY} (3,606 t) target since 1993 and it is currently at 55% of this proposed recovery target.

DISTRIBUTION TARGET

There has been a reduction in the area occupied (DWAO) by White Hake in NAFO Divisions 4RS (Fig. 20). The proposed distribution target for recovery is for White Hake to return to its

distribution as seen during the productive period (1985 to 1990). Currently in the last five years, the area occupied by total White Hake population in the nGSL represents close to 65% of the area occupied between 1985 and 1990.

EXPECTED POPULATION TRAJECTORY

Considering the low level of landings and the stable adult population size from summer survey index since 1995, no change in population size is expected in the near future under the current conditions. No population projections could be conducted for this management unit.

MITIGATION MEASURES

There is no directed White Hake fishery in Divs. 4RS, however there are some management measures in place in other directed fisheries that can mitigate threats to White Hake. These include:

- A small fish protocol regulation resulting in possible area closures when the number of White Hake caught below the minimum size (45 cm) is greater than 15% of the catch.
- A White Hake bycatch limit of 10% in other directed fisheries.
- Mandatory landing of all White Hake caught.
- Minimum levels of at-sea observer coverage on trips in directed fisheries.
- Dockside monitoring program (DMP) of all catches with mandatory notification on leaving and returning to port.

ALLOWABLE HARM

There is no directed White Hake fishery in Divs. 4RS. White Hake fishing mortality comes mainly from accounted bycatch in other directed groundfish fisheries and unaccounted bycatch in the shrimp fishery. Since 1995, reported landings have been approximately 11 t per year representing a relative fishing mortality of 0.007 (Fig. 38). Bycatch of small White Hake in the shrimp fishery is estimated to be 0.7 t annually. These sources of fishing mortality are considered as having a negligible impact on the recovery potential of White Hake in 4RS.

SUMMARY

Geographic distributions indicate that White Hake is present in several of the deeper areas in the nGSL. Concentrations are seen along the 200 m isobath of the southern flank of the Laurentian Channel and offshore of St. George's Bay on the west coast of Newfoundland. Specimens were generally absent on shelves < 200 m. Maps showing distribution of White Hake in nGSL surveys suggest the connectivity of Divisions 4RS with populations to the south of Newfoundland.

The abundance indices from summer surveys show high abundances of White Hake between 1985 and 1990, with a marked decrease thereafter, down to a minimum in 1994. The abundance was low and stable up to 2014. Declines of 82% and 71%, depending upon the survey gear/vessel combination, were observed between 1985 and 2014 for the total population and between 1987 and 2014 for mature portion of the population, respectively.

White Hake abundances peaked at depths between 250 and 300 m and temperatures of 5 to 6.5°C. Highest catch rates in the summer surveys were observed in the deepwater slope

habitats. The geographic distributions of immature (< 45 cm) and adult (≥ 45 cm) White Hake indicate that they are found in the same area in the nGSL. Comparison of depths in the July, August, October, and January surveys indicate that the species occupies the same depth range during all seasons, although they are more concentrated in deeper waters in winter.

Area occupied by total and mature size groups of White Hake also declined over time. Total area occupied by White Hake averaged 47,500 km^2 for the 1985-1990 period and decreased to an average of 26,650 km^2 for the period 1992-2014.

Shoreline surveys in eelgrass beds have reported the presence of small individuals (< 30 cm), whereas spawning, eggs, and larval White Hake are as yet unconfirmed in the region.

An examination of predator stomach contents revealed that White Hake was insignificant or absent as prey for Greenland Halibut, Atlantic Halibut, and Atlantic Cod. Grey seals caught near Anticosti Island, but not western Newfoundland, had White Hake in small amounts in their stomachs. Overwintering seals sampled near the Laurentian Channel (Cape Breton/Cabot Strait area) area did show significant predation, particularly for hake ranging in size from 25-60 cm. However, it is not known if the increase in seal population in the Gulf could result in higher predation rates on White Hake from the 4RS Divisions.

NGSL White Hake mature abundance is presently below the proposed biomass and distribution recovery targets. It is currently at 55% of the proposed biomass recovery target and at 65% of the proposed distribution target.

Considering the low level of landings and the stable adult population size from summer survey index since 1995, no change in population size is expected in the near future under the current conditions.

Information on potential threats to White Hake in the nGSL is limited. White Hake has never supported a directed fishery and most of the landings are from bycatch in other fisheries. These landings were mainly bycatch in Atlantic Halibut, Atlantic Cod, Redfish, and Greenland Halibut fisheries. Management measures in place since 1995, including bycatch limits, small fish protocols, and dock side monitoring help mitigate threats to White Hake. Total bycatch in the nGSL since 1995 remains at a low level (around 11 t per year). Relative fishing mortality (*F*) of 0.007 is considered as having a negligible impact on the recovery potential of White Hake.

A source of unaccounted fishing mortality comes from bycatch and at-sea discarding by the shrimp fleet in 4RS. An estimation of this discard would be of less than 1 t annually, and would represent 1% of the estimated trawlable biomass. This would not be considered as a significant source of mortality.

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TABLES

Table 1. Surveys conducted in the northern Gulf of St. Lawrence 1978-2014.

Surveys	Vessel	Vessel Size (m)	Year	Month	Gear	NAFO	Coverage	Tow duration (min)	Tow speed (knots)	Wing spread (ft)
DFO - Winter	*Gadus Atlantica*	73.8	1978-1994 No survey in 1982	Jan.	Engels 145 Hi-Lift Codend liiner mesh size:30 mm	3Pn, 4RST	Strata >50 fathoms Estuary not covered Average area: 31,700-100,400 km^2 3Pn and 4R well covered	30	3.5	45
DFO - Summer	*Lady Hammond*	58	1984-1990	Aug.	Western IIA Codend liner mesh size: 33/19 mm	4RST	Strata>50 fathoms Estuary sparsely covered Average area: 85,300 km^2	30	3.5	41
	Alfred Needler	50.3	1990-2005 No survey in 2004	Aug.	URI shrimp trawl 81'/114' Codend liner mesh size:19 mm	3Pn, 4RST	Addition of shallow strata: 20-50 fathoms 3Pn covered from 1993 -2003 Area 95,070 – 119,000 km^2	24	3	44
	Teleost	63	2004-2014	Aug.	Campelen 1800 Rock Hopper foot gear Codend liner mesh size: 12.7 mm	4RST	3Pn is no longer covered Average area: 114,482 km^2	15	3	55.6
Industry	Sentinel commercial boats from QC and NL regions	13.72-19.81	1995-2014	July	Star Balloon 300 Rock Hopper foot gear Codend liner mesh size: 40 mm Restrictor cable	3Pn, 4RST	Estuary not covered Average area: 114,482 km^2 Range: 109,008-117,449 km^2	30	2.5	54
	Sentinel commercial boats from QC and NL regions	13.72-19.81	1995-2002	Oct.	Star Balloon 300 Rock Hopper foot gear Codend liner mesh size: 40 mm Restrictor cable	3Pn, 4RST	Estuary not covered Average area 112,595 km^2 Range: 100,598-116,420 km^2	30	2.5	54

Table 2. List of bottom trawl surveys conducted in the northern Gulf of St. Lawrence during the 1978-2014 period.

Year	**January** DFO Winter	**July** Sentinel Mobile Summer	**August** DFO Summer	**October** Sentinel Mobile Fall
1978	*Gadus* – Engel 145			
1979	*Gadus* – Engel 145			
1980	*Gadus* – Engel 145			
1981	*Gadus* – Engel 145			
1982				
1983	*Gadus* – Engel 145			
1984	*Gadus* – Engel 145		*Lady Hammond* – WIIA	
1985	*Gadus* – Engel 145		*Lady Hammond* – WIIA	
1986	*Gadus* – Engel 145		*Lady Hammond* – WIIA	
1987	*Gadus* – Engel 145		*Lady Hammond* – WIIA	
1988	*Gadus* – Engel 145		*Lady Hammond* – WIIA	
1989	*Gadus* – Engel 145		*Lady Hammond* – WIIA	
1990	*Gadus* – Engel 145		*LH/AN*	
1991	*Gadus* – Engel 145		*Alfred Needler* – URI	
1992	*Gadus* – Engel 145		*Alfred Needler* – URI	
1993	*Gadus* – Engel 145		*Alfred Needler* – URI	
1994	*Gadus* – Engel 145		*Alfred Needler* – URI	
1995		C. trawlers – S. B. 300	*Alfred Needler* – URI	C. trawlers – S. B. 300
1996		C. trawlers – S. B. 300	*Alfred Needler* – URI	C. trawlers – S. B. 300
1997		C. trawlers – S. B. 300	*Alfred Needler* – URI	C. trawlers – S. B. 300
1998		C. trawlers – S. B. 300	*Alfred Needler* – URI	C. trawlers – S. B. 300
1999		C. trawlers – S. B. 300	*Alfred Needler* – URI	C. trawlers – S. B. 300
2000		C. trawlers – S. B. 300	*Alfred Needler* – URI	C. trawlers – S. B. 300
2001		C. trawlers – S. B. 300	*Alfred Needler* – URI	C. trawlers – S. B. 300
2002		C. trawlers – S. B. 300	*Alfred Needler* – URI	C. trawlers – S. B. 300
2003		C. trawlers – S. B. 300	*Alfred Needler* – URI	C. trawlers – S. B. 300
2004		C. trawlers – S. B. 300	*Teleost* - Campelen	
2005		C. trawlers – S. B. 300	*TE/AN*	
2006		C. trawlers – S. B. 300	*Teleost* – Campelen	
2007		C. trawlers – S. B. 300	*Teleost* – Campelen	
2008		C. trawlers – S. B. 300	*Teleost* – Campelen	
2009		C. trawlers – S. B. 300	*Teleost* – Campelen	
2010		C. trawlers – S. B. 300	*Teleost* – Campelen	
2011		C. trawlers – S. B. 300	*Teleost* – Campelen	
2012		C. trawlers – S. B. 300	*Teleost* – Campelen	
2013		C. trawlers – S. B. 300	*Teleost* – Campelen	
2014		C. trawlers – S. B. 300	*Teleost* – Campelen	

Dark grey = comparative fishing experiment
Gadus = *Gadus Atlantica*; C. Trawler – S. B. 300 = Commercial trawlers – Star Balloon 300; WIIA = Western IIA; URI = University of Rhode Island shrimp trawl

Table 3. White Hake mean number per tow, abundance, mean weight per tow and biomass from the Winter - January Gadus Atlantica *DFO research survey in NAFO Division 4R and subdivision 3Pn from 1978 to 1994.*

Subdivision 3Pn - January

Year	Area (km^2)	Number /tow	95% CI	Abundance ('000s)	95% CI	Weight (kg) / tow	95% CI	Biomass (t)	95% CI
1978	5594	3.94	3.20	482	391	5.43	3.64	664	445
1979	5594	5.72	5.45	700	667	11.04	4.48	1351	548
1980	5594	5.11	5.66	625	692	13.61	39.60	1665	4845
1981	5594	8.70	6.99	1065	856	18.67	14.88	2285	1821
1982									
1983	5594	3.23	3.19	396	391	9.26	9.78	1133	1197
1984	5594	2.81	1.71	344	209	6.06	3.34	741	409
1985	5594	5.32	3.36	650	412	12.73	10.99	1557	1344
1986	5594	9.24	3.23	1130	395	19.73	7.77	2414	951
1987	5594	12.59	8.79	1541	1076	29.25	22.55	3579	2759
1988	5594	3.97	2.44	486	299	8.52	4.79	1042	586
1989	5594	3.30	1.13	403	138	5.82	4.29	712	525
1990	5594	3.36	1.86	411	228	4.68	2.25	572	276
1991	5594	5.17	1.64	632	201	8.49	3.33	1039	407
1992	5594	4.89	2.49	599	304	5.51	2.16	674	264
1993	5594	3.36	0.99	412	121	2.78	0.88	341	107
1994	5594	3.43	1.17	419	143	3.45	1.45	422	177

Division 4R – January

Year	Area (km^2)	Number /tow	95% CI	Abundance ('000s)	95% CI	Weight (kg) / tow	95% CI	Biomass (t)	95% CI
1978	19667	1.84	1.69	792	726	1.99	1.57	856	676
1979	19667	1.57	0.79	677	342	1.67	0.81	718	348
1980	19667	2.35	3.14	1011	1349	4.04	3.84	1738	1653
1981	19667	5.86	4.33	2522	1864	9.50	17.22	4087	7406
1982									
1983	19667	1.43	0.66	614	284	2.66	1.64	1142	707
1984	19667	2.66	1.04	1142	449	5.31	2.54	2282	1092
1985	19667	4.94	3.51	2123	1510	5.75	3.82	2474	1644
1986	19667	3.21	1.31	1382	562	4.96	1.92	2132	827
1987	19667	0.54	0.35	234	152	0.64	1.24	277	535
1988	19667	0.23	0.62	99	266	0.50	1.85	213	794
1989	19667	0.33	0.27	142	118	0.17	0.08	73	35
1990	19667	0.63	0.22	270	95	0.67	0.74	288	317
1991	19667	0.52	0.24	223	102	0.44	0.22	190	94
1992	19667	0.34	0.19	145	81	0.36	0.21	153	90
1993	19667	0.43	0.35	185	149	0.21	0.14	90	59
1994	19667	0.52	0.34	224	145	0.33	0.15	141	63

Table 4. White Hake total, mature and immature size group (immature < 45 cm, mature ≥ 45 cm) abundances ('000s) in NAFO Divisions 4RST from the August DFO research surveys from 1985 to 2014. Data presented in* Lady Hammond-*Western IIA equivalent units.*

Divisions 4RST* - August – Lady Hammond-Western IIA equivalent

Year	Area (km^2)	Total Abundance	95% CI	Mature (≥ 45 cm)	95% CI	Immature (< 45 cm)	95% CI
1985	109412	9120	2283				
1986	109412	12451	2549				
1987	109412	12874	3650	6632	1764	6242	6825
1988	109412	8781	2651	5324	942	3456	3626
1989	109412	8637	2049	4310	787	4326	1477
1990	109412	9683	1397	4723	820	4961	909
1991	109412	6064	1218	2950	751	3115	663
1992	109412	3464	985	1787	839	1677	392
1993	109412	1757	1106	730	564	1027	680
1994	109412	1466	489	511	320	955	371
1995	109412	2864	1770	1587	1659	1278	448
1996	109412	1660	493	731	423	929	372
1997	109412	3105	1449	1264	594	1841	1255
1998	109412	2148	787	1041	459	1107	527
1999	109412	2755	1015	992	492	1763	728
2000	109412	4675	1869	1820	906	2854	2177
2001	109412	3458	1019	1443	723	2015	542
2002	109412	1438	924	725	551	713	382
2003	109412	2508	926	1361	579	1147	485
2004	109412	2061	1721	989	673	1072	1694
2005	109412	1626	485	1003	347	623	283
2006	109412	1374	329	872	327	501	171
2007	109412	1583	615	861	452	722	594
2008	109412	2120	507	1192	416	928	250
2009	109412	1462	621	670	423	792	270
2010	109412	1909	605	593	330	1316	541
2011	109412	2567	610	1116	454	1451	649
2012	109412	1695	512	1217	442	478	218
2013	109412	2941	1765	1595	2331	1346	761
2014	109412	3128	749	1289	471	1839	582

Table 5. White Hake total, mature and immature size group (immature < 45 cm, mature ≥ 45 cm) abundances ('000s) in NAFO Divisions 4RST from the August DFO research surveys, from 1985 to 2014. Data presented in* Teleost-Campelen equivalent units.

Divisions 4RST* - August – Teleost - Campelen equivalent

Year	Area (km2)	Total Abundance	95% CI	Mature (≥ 45 cm)	95% CI	Immature (< 45 cm)	95% CI
1985	109412	30984	7757				
1986	109412	41563	8507				
1987	109412	30803	37242	5603	1408	25200	43774
1988	109412	19637	15229	5966	1019	13671	16119
1989	109412	23840	9551	5083	998	18757	8928
1990	109412	27017	4547	5352	950	21665	4161
1991	109412	17230	3414	3655	975	13575	2818
1992	109412	9284	2157	2169	1311	7108	1757
1993	109412	4932	2768	940	822	3992	2143
1994	109412	4772	1552	717	444	4055	1497
1995	109412	6961	2308	1653	1498	5251	1747
1996	109412	5148	1823	958	514	4191	1780
1997	109412	10555	7119	1550	854	9005	6998
1998	109412	6437	2502	1452	657	5065	2344
1999	109412	8605	3640	1240	614	7620	3446
2000	109412	17133	18201	2163	768	15031	18444
2001	109412	10968	2846	1951	982	9018	2470
2002	109412	4181	2346	1069	786	3161	1763
2003	109412	6237	2548	1618	707	4619	2076
2004	109412	6652	12085	1077	693	5575	11921
2005	109412	3752	1219	1241	415	2511	1064
2006	109412	3160	833	1033	376	2127	838
2007	109412	3635	2365	967	466	2668	2311
2008	109412	5500	1271	1400	415	4099	1168
2009	109412	4125	1508	788	489	3337	1149
2010	109412	6449	2470	727	371	5722	2469
2011	109412	6992	1945	1582	547	5409	2064
2012	109412	3119	1060	1430	535	1689	801
2013	109412	7746	3887	1436	2311	6310	3900
2014	109412	8875	2422	1589	473	7286	2453

Table 6. White Hake mean number per tow, total abundance, mean weight per tow and total biomass from the July sentinel mobile survey in NAFO Divisions 4RS and subdivision 3Pn from 1995 to 2014.

Divisions 4R and 4S - July

Year	Area (km2)	number / tow	95% CI	Abundance ('000s)	95% CI	Weight / tow	95% CI	Biomass (t)	95% CI
1995	91358	1.44	0.46	3458	1112	1.29	0.49	3101	1178
1996	92521	0.66	0.2	1602	479	0.43	0.13	1039	315
1997	92926	0.44	0.13	1061	326	0.38	0.13	933	320
1998	96565	1.03	0.31	2603	793	0.79	0.23	2003	576
1999	96565	0.4	0.18	1022	456	0.28	0.1	699	257
2000	96565	1.56	0.73	3961	1855	0.73	0.23	1854	594
2001	90772	1.96	0.92	4669	2182	1.22	0.51	2906	1207
2002	93334	1.3	0.96	3175	2355	0.96	0.57	2350	1387
2003	96565	0.37	0.22	947	558	0.47	0.24	1201	608
2004	90803	0.67	0.84	1595	2001	1.12	1.4	2668	3341
2005	95124	0.34	0.13	837	334	0.3	0.12	746	287
2006	96565	0.45	0.19	1130	474	0.45	0.41	1142	1042
2007	94130	0.28	0.09	680	228	0.2	0.06	490	158
2008	94130	0.23	0.1	571	257	0.2	0.09	488	234
2009	93872	0.2	0.09	491	225	0.15	0.06	366	153
2010	92926	0.87	0.38	2121	927	0.47	0.17	1142	422
2011	95124	0.17	0.08	426	188	0.13	0.07	334	172
2012	94545	0.3	0.11	744	279	0.35	0.17	881	431
2013	96565	0.24	0.16	601	407	0.16	0.09	399	226
2014	93313	0.21	0.1	514	256	0.18	0.17	446	427

Subdivision 3Pn - July

Year	Area (km2)	number / tow	95% CI	Abundance ('000s)	95% CI	Weight / tow	95% CI	Biomass (t)	95% CI
1995	5594	2.16	1.66	317	243	1.44	1.56	211	229
1996	5594	0.69	0.86	101	126	0.81	1.34	120	197
1997	5594	0.86	2	126	294	0.56	1.12	82	165
1998	5594	2.65	1.95	389	286	1.76	1.67	258	245
1999	5594	4.16	2.32	611	341	2.59	1.67	380	245
2000	5594	4.5	2.16	660	316	2.47	1.16	363	170
2001	5594	5.07	2.33	744	342	4.02	1.84	590	271
2002	5594	2.31	1.58	339	232	1.97	1.5	289	220
2003	5594	2.98	2.88	437	422	2.08	2.35	306	345
2004	5594	1.99	2.11	292	309	0.95	0.87	140	128
2005	5594	1.86	1.67	273	245	1.8	2.21	265	324
2006	5594	2.38	1.46	350	214	1.47	0.67	216	98
2007	5594	0.58	0.41	85	60	0.57	0.57	83	84
2008	5594	0.59	0.22	86	32	0.22	0.11	33	17
2009	5594	1.1	0.75	162	111	0.32	0.24	46	35
2010	5594	2.14	1.22	314	179	0.89	0.84	130	123
2011	5594	0	0	0	0	0	0	0	0
2012	5594	0.8	1	117	147	0.77	0.95	113	140
2013	5594	1.05	0.98	154	144	0.85	1.13	124	166
2014	5594	1.3	1.22	191	180	0.82	0.9	120	133

Table 7. Rates of decline in the nGSL White Hake for total abundance, mature (≥ 45 cm), and immature (< 45 cm) size group abundances based on the August RV survey in Lady Hammond-*Western IIA equivalent unit and in* Teleost-*Campelen equivalent unit.*

	Population	Log model Linear regression	Years	Slope	Percent decline
Lady Hammond - Western IIA equivalent	Total	y = -0.056x+126.2	29	-0.056	80
	Mature	y = -0.047 + 108.3	27	-0.047	72
	Immature	y = -0.052 + 117.8	27	-0.052	75
Teleost - Campelen equivalent	Total	y = -0.060 + 135.6	29	-0.060	82
	Mature	y = -0.046 + 106.2	27	-0.046	71
	Immature	y = -0.053 + 121.4	27	-0.053	76

Table 8. Annual landings (t) of White Hake in NAFO Divisions 4R and 4S, in directed fishery, as bycatch, and total, from 1960 to 2014.

	4R			4S			4RS		
Year	Directed	Bycatch	Total	Directed	Bycatch	Total	Directed	Bycatch	Total
1960		15	15		31	31	0	46	**46**
1961		7	7		16	16	0	23	**23**
1962		8	8	1	18	19	1	26	**27**
1963		3	3		26	26	0	29	**29**
1964		8	8		159	159	0	167	**167**
1965		2	2		0	0	0	2	**2**
1966		50	50		20	20	0	70	**70**
1967		11	11		22	22	0	33	**33**
1968		24	24		8	8	0	32	**32**
1969		53	53		6	6	0	59	**59**
1970		93	93		34	34	0	127	**127**
1971		89	89		46	46	0	135	**135**
1972		57	57		17	17	0	74	**74**
1973		76	76		38	38	0	114	**114**
1974		98	98		47	47	0	145	**145**
1975		71	71		49	49	0	120	**120**
1976		146	146		102	102	0	248	**248**
1977		123	123		134	134	0	257	**257**
1978		103	103	78	72	150	78	175	**253**
1979		158	158		83	83	0	241	**241**
1980		163	163		153	153	0	316	**316**
1981		77	77		91	91	0	168	**168**
1982		101	101	21	332	353	21	433	**454**
1983		56	56		9	9	0	65	**65**
1984		66	66	12	40	52	12	106	**118**
1985		88	88		12	12	0	100	**100**
1986		164	164		66	66	0	230	**230**
1987	31	67	98		92	92	31	159	**190**
1988	11	38	49	8	50	58	19	88	**107**
1989		43	43	24	42	66	24	85	**109**
1990	3	41	43		49	49	3	89	**92**
1991	4	42	46	12	98	110	16	141	**157**
1992	8	77	84	11	70	81	18	147	**165**
1993	20	107	127	11	44	55	31	151	**182**
1994	0	89	89	0	37	37	0	126	**126**
1995		6	6		1	1	0	8	**8**
1996		14	14		11	11	0	24	**24**
1997		1	1		6	6	0	7	**7**
1998	0	7	7	0	6	6	0	13	**13**
1999	1	6	7		2	2	1	8	**9**

Table 8. Continued

Year	4R Directed	4R Bycatch	4R Total	4S Directed	4S Bycatch	4S Total	4RS Directed	4RS Bycatch	4RS Total
2000		9	9	0	3	3	0	12	12
2001		12	12		3	3		15	15
2002		10	10		7	7		17	17
2003		12	12		1	1		13	13
2004		16	16		1	1		17	17
2005		10	10	1	2	4	1	13	14
2006		5	5		1	1		6	6
2007		7	7		1	1		8	8
2008		13	13		1	1		15	15
2009		4	4		1	1		6	6
2010	0	5	5		2	2	0	6	7
2011		7	7		3	3		10	10
2012		10	10		4	4		14	14
2013*		6	6		4	4		10	10
2014*		3	3		2	2		4	4

(* = preliminary data)

Table 9. Fishery related losses (t) of White Hake in commercial fisheries and scientific activities in NAFO Div. 4RS.

			Mean (t) 2009-2013 Division		
	Gear	**Directed fishery**	**4R**	**4S**	**Size group**
Groundfish fishery	Trawl	Redfish	0.5184	0.1918	Adult
	Gillnet[1]	Cod	1.3834	0.0002	Adult
		American Plaice	0.1324		Adult
		Greenland Halibut	1.2868	2.3310	Adult
		Unknown		0.0112	Adult
	Hand line	Cod	0.0072		Adult
	Longline[1]	Atlantic Halibut	2.0108	0.1520	Adult
		White Hake	0.0052		Adult
		Cod	0.2460	0.0230	Adult
		Unknown		0.0016	Adult
	Seine	Witch Flounder	0.2616		Adult
		Redfish	0.5992		Adult
		Greenland Halibut	0.0004		Adult
	Unknown	Redfish		0.0110	Adult
		Unknown		0.4258	-
Scientific (DFO & Sentinel surveys)	Trawl		0.0622	0.0819	All stages
Shrimp fishery unreported bycatch	Shrimp trawl	Shrimp	0.6		Juvenile 20-26 cm

[1] Includes sentinel fishery landings

Table 10. Total estimated unreported bycatch (t) of White Hake in the Gulf of St. Lawrence shrimp fishery from 2000 to 2013 as estimated from the observer database.

Year	Bycatch (t)
2000	0.58
2001	0.20
2002	0.22
2003	0.88
2004	0.63
2005	0.18
2006	1.13
2007	1.78
2008	1.11
2009	0.93
2010	0.68
2011	0.50
2012	0.26
2013	1.1

FIGURES

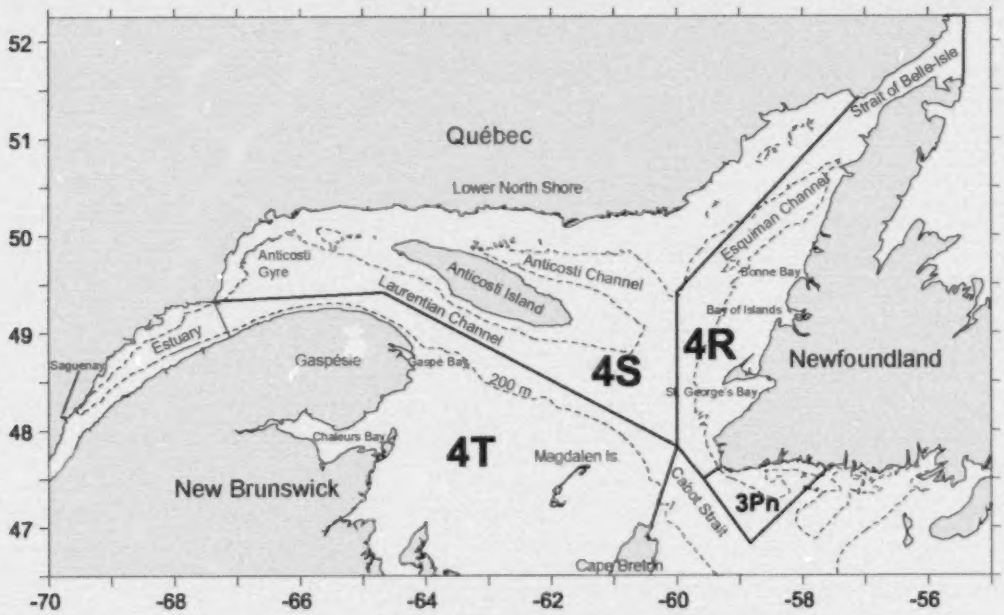


Figure 1. Gulf of St. Lawrence with NAFO Divisions and locations cited in report.

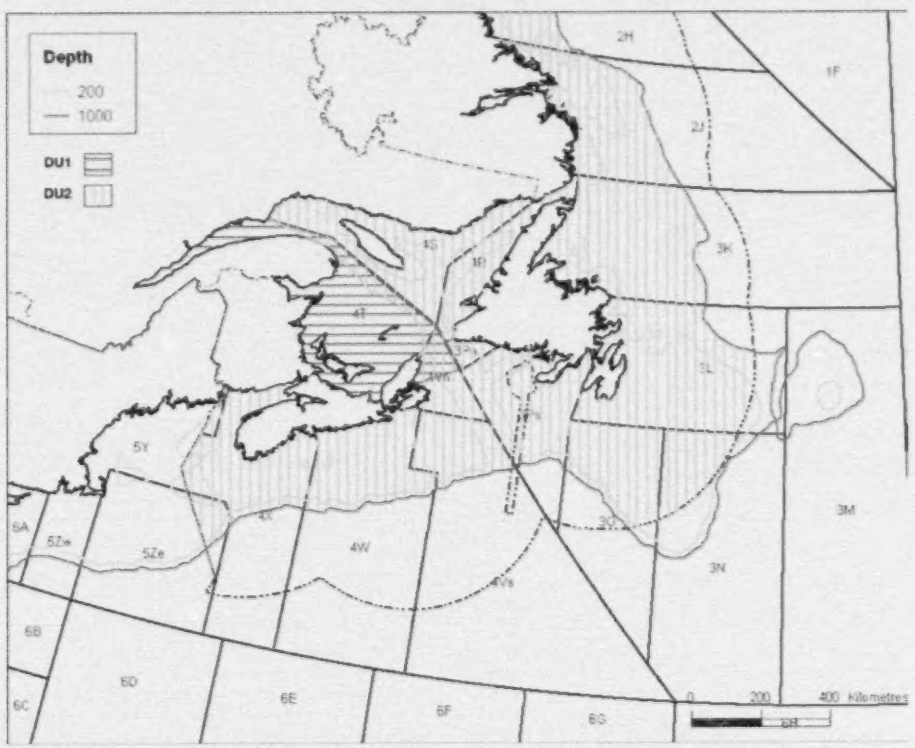


Figure 2. Boundaries of the two White Hake designatable unit identified by COSEWIC and the area of overlap between them. (DU1=Southern Gulf of St. Lawrence population, DU2= Scotian Shelf, Northern Gulf of St. Lawrence and Southern Newfoundland) (from COSEWIC 2013).

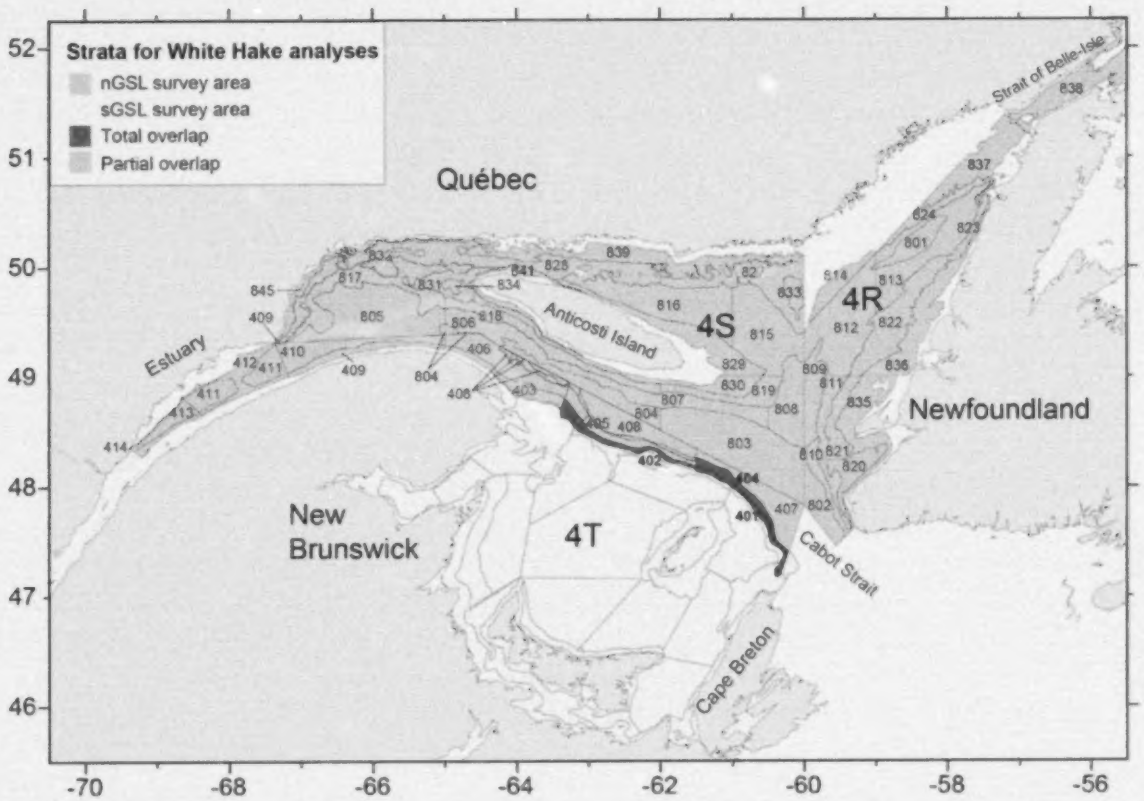


Figure 3. Northern and southern Gulf of St. Lawrence DFO groundfish survey areas. Strata numbers are shown for nGSL. Blue and light green (partial overlap Division 4T strata 403, 405-408) areas are identified as 4RST and are the nGSL portion of DU2. Dark green, strata fully overlapping (401, 402, 404) with sGSL are excluded from analyses of DU2.*

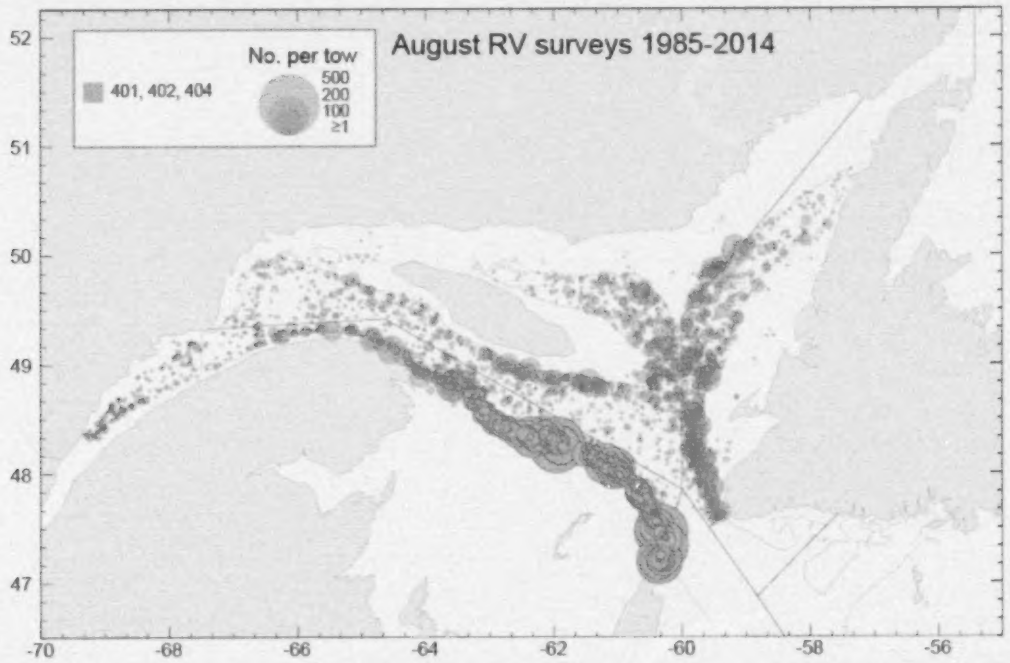


Figure 4. Geographic distribution of White Hake catches in the nGSL August DFO RV survey series in all strata of NAFO Divisions 4RST over the period 1985-2014. Relative abundance is shown with number per tow proportional to circle size and expressed in Lady Hammond-*Western IIA equivalent units. Grey circles = 4T strata 401, 402, and 404 excluded from Atlantic and Northern Gulf of St. Lawrence population analyses.*

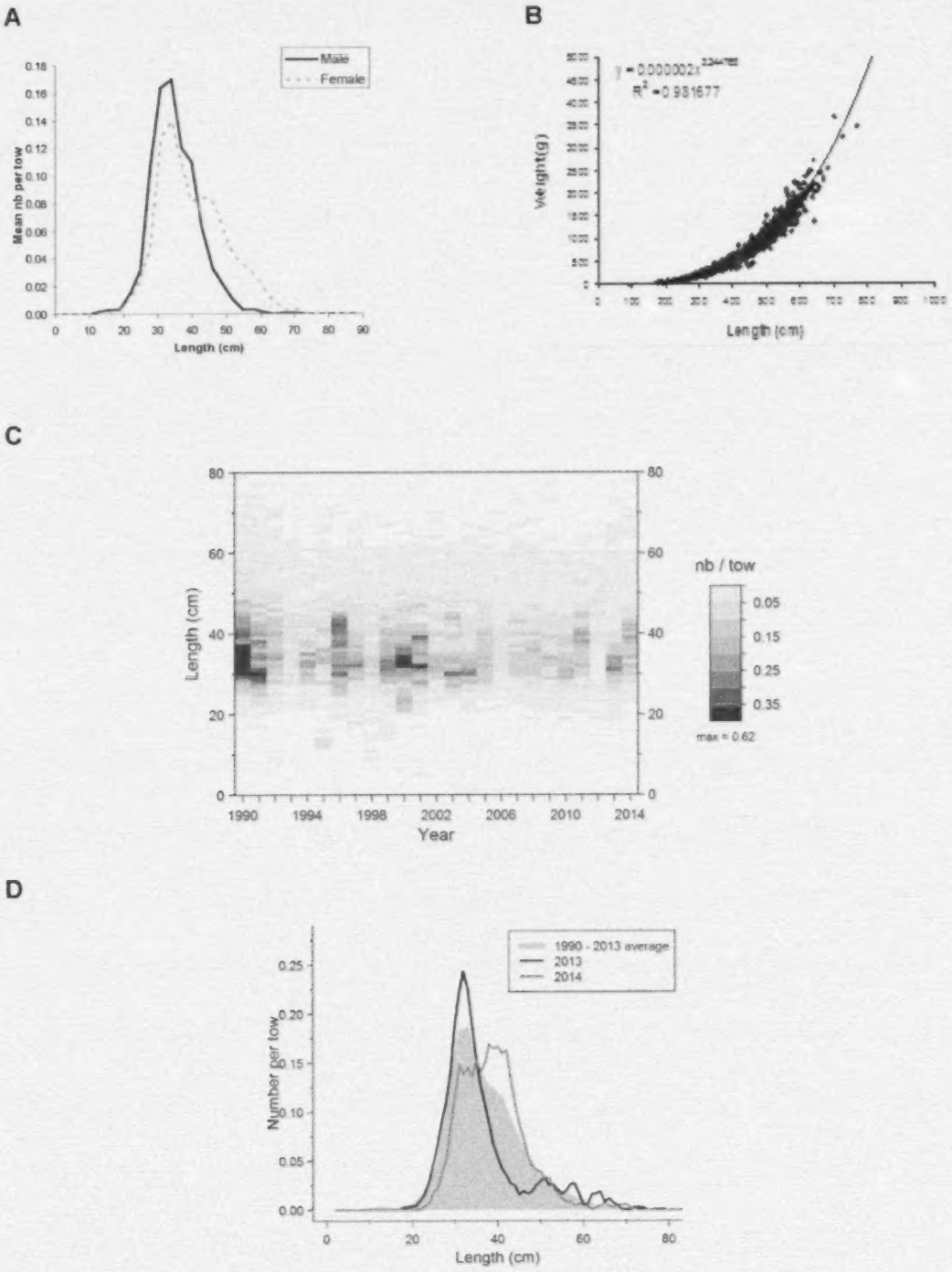
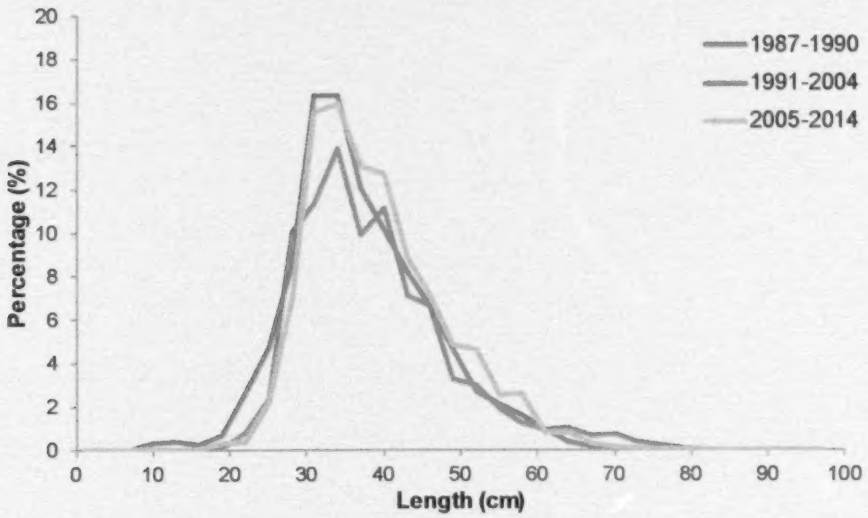


Figure 5. Biological data for White Hake on the August survey series, in Teleost-*Campelen equivalent units. A) Length frequency distribution by sex for the period 1990-2014. B) Length-weight relationship. C) Annual abundance by length distribution (mean number per 15 minute tow). D) Length frequency distributions (mean number per 15 minute tow).*

A)



B)

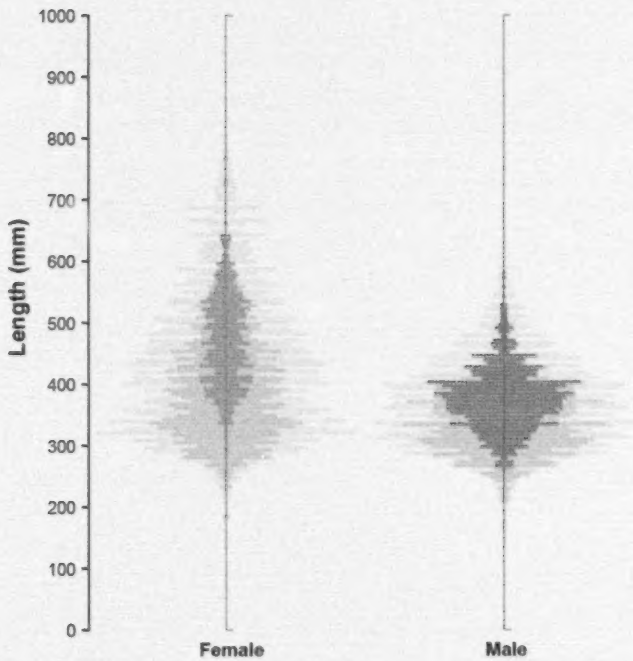


Figure 6. A) Length distribution (% at length) by time periods of White Hake in the summer RV survey from 4RS, 1987 to 2014. B) Frequency dot plots of White Hake on August surveys by length (mm) and classed by sex. Dark colour = individuals classed as mature. Light colour = total of individuals examined for maturity. Grey = additional individuals only examined for sex.

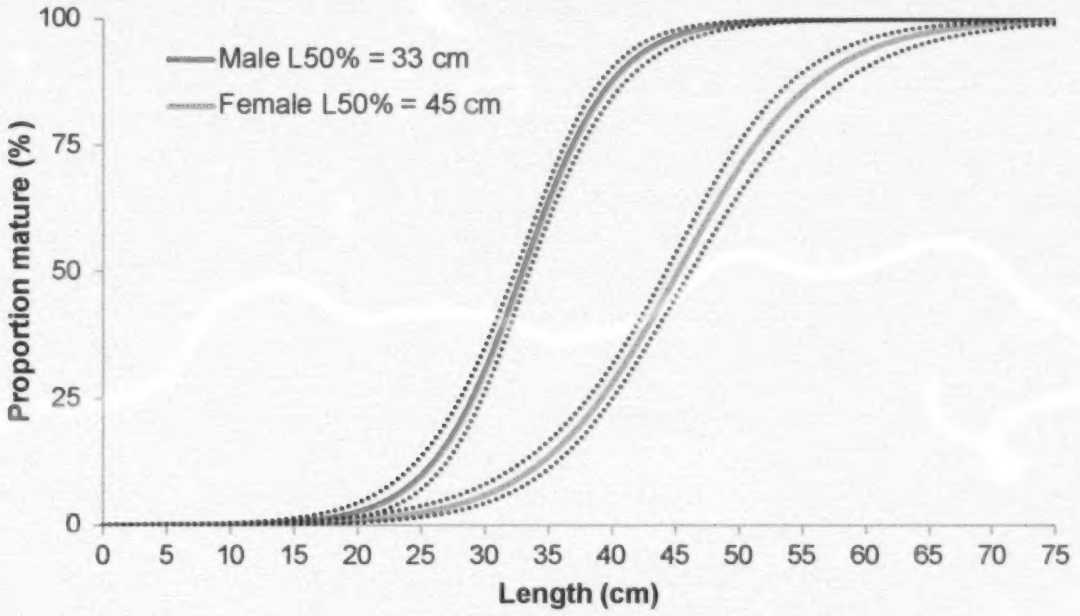


Figure 7. Maturity ogives for male and female White Hake in the nGSL estimated from data collected on the August DFO survey. The solid lines are the mean and the dotted lines are 95% CI.

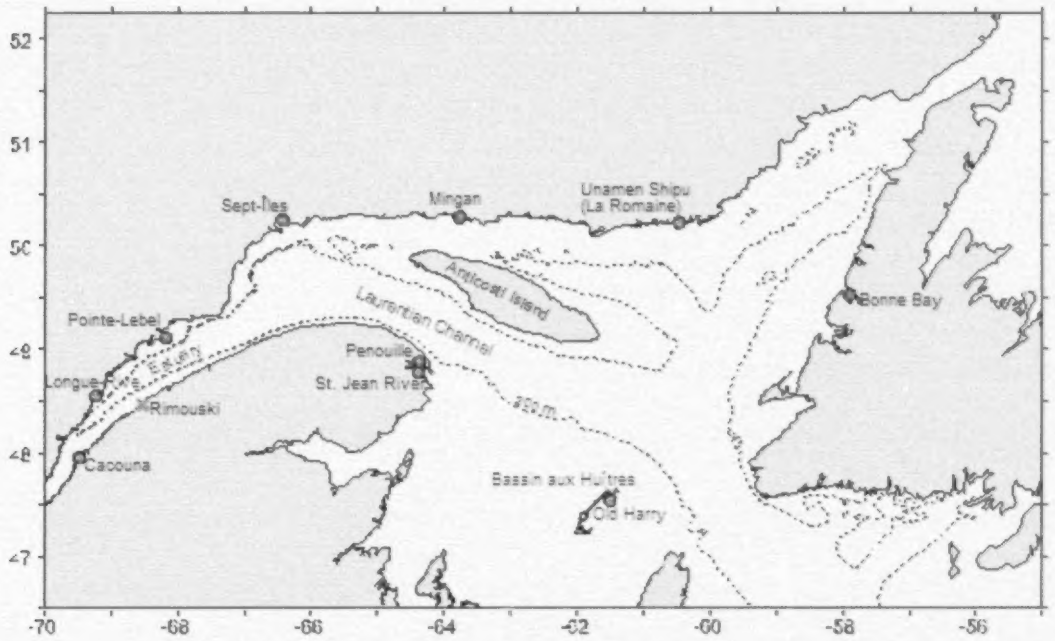


Figure 8. Presence of White Hake within 11 eelgrass beds sampled for fishes from 2005 to 2013 in the Gulf of St. Lawrence. Green dot= White Hake present, red x = White Hake absent.

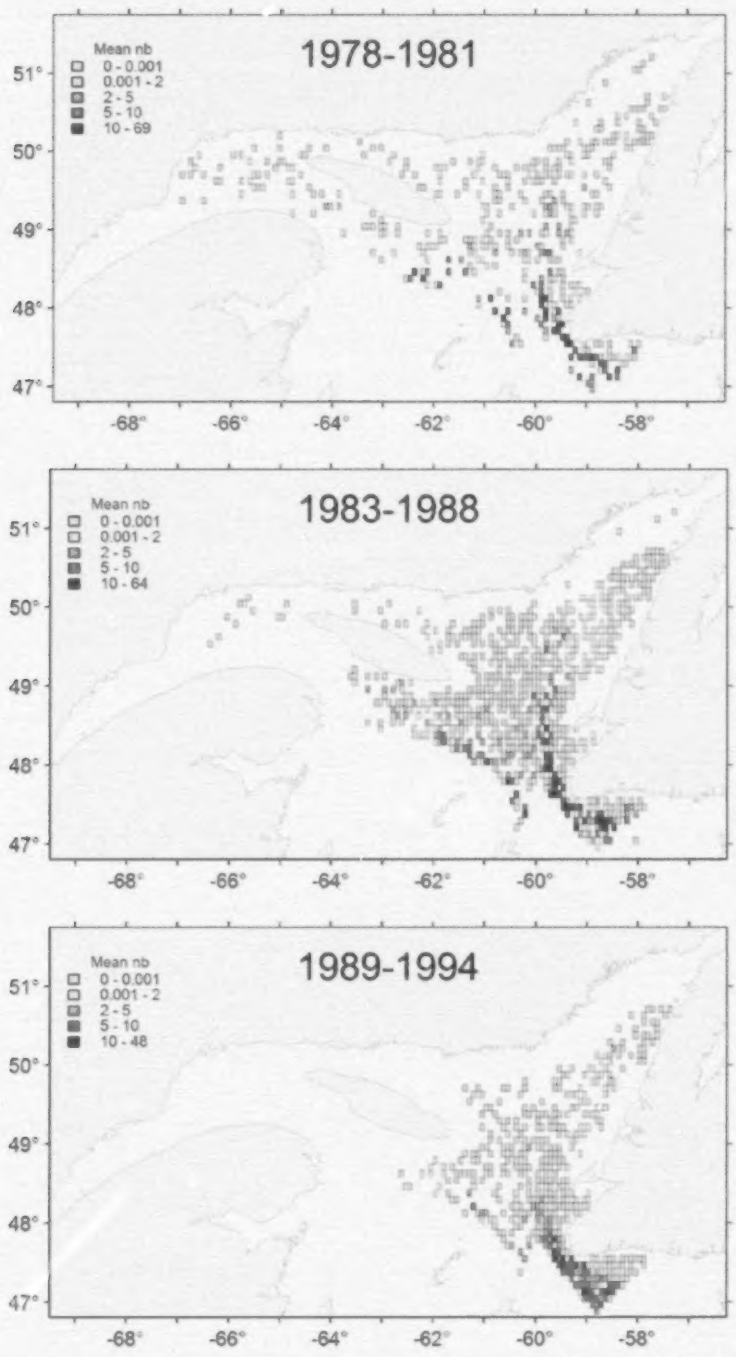


Figure 9. Geographic distribution of White Hake catches (mean number per tow for the respective time period) in the Gadus-*Engel January surveys of the northern Gulf of St. Lawrence (Divisions 4RST and subdivision 3Pn).*

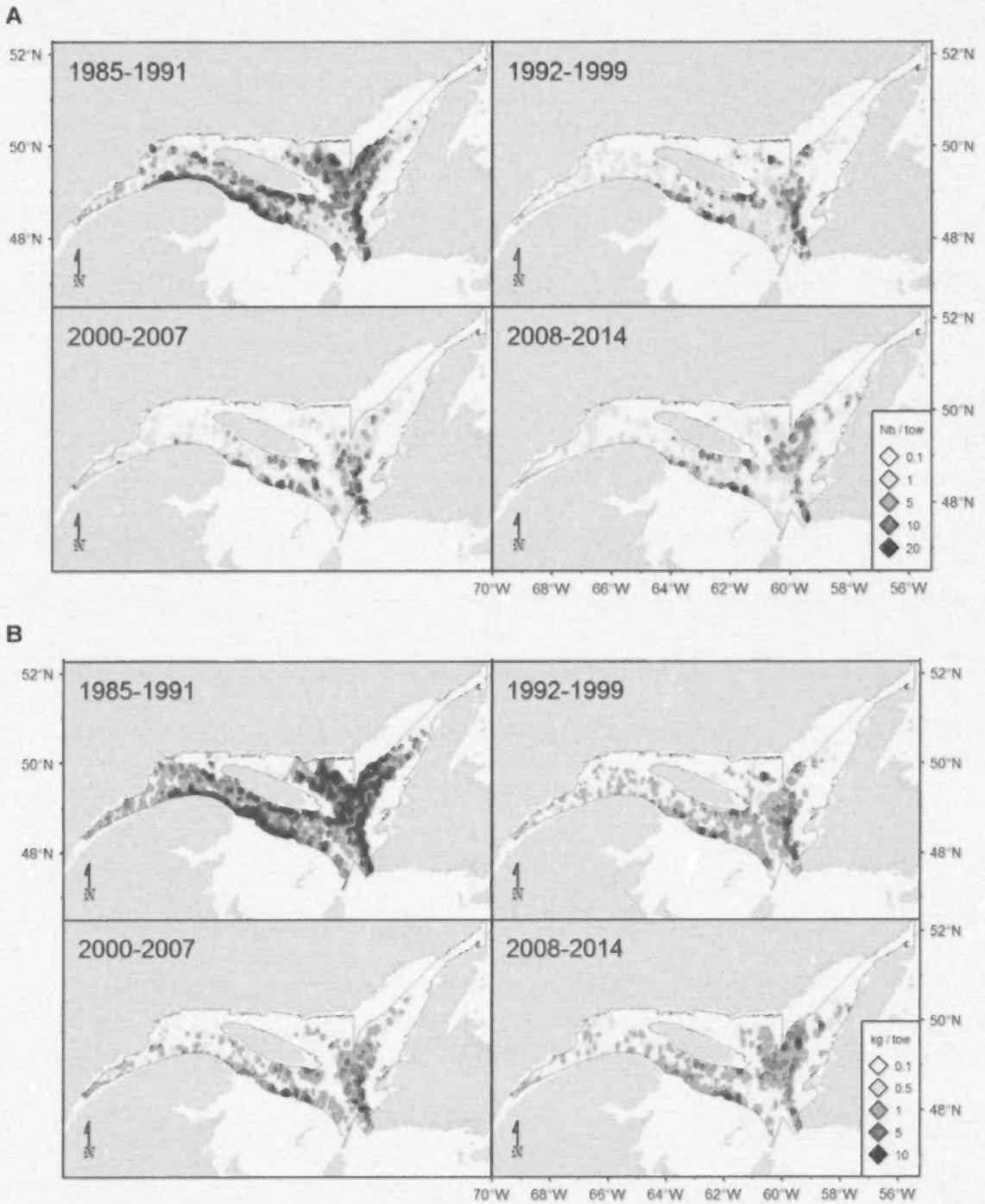


Figure 10. Geographic distribution of White Hake catches in Divs. 4RST of the August survey series 1985-2014 in* Teleost-*Campelen equivalent: A) Standardized number per tow B) Standardized weight per tow.*

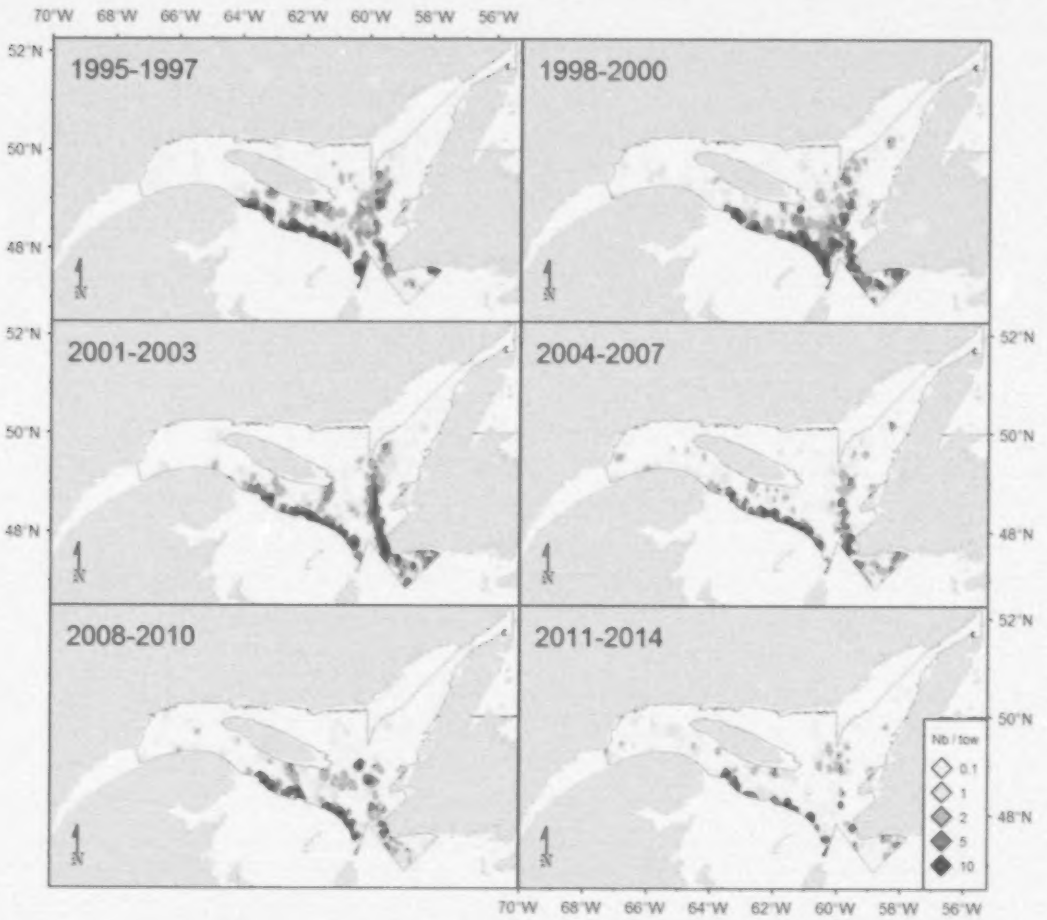


Figure 11. Geographic distribution of White Hake catches (standardized number per tow) in 3Pn4RST from the Sentinel Mobile July survey series, 1995-2014.

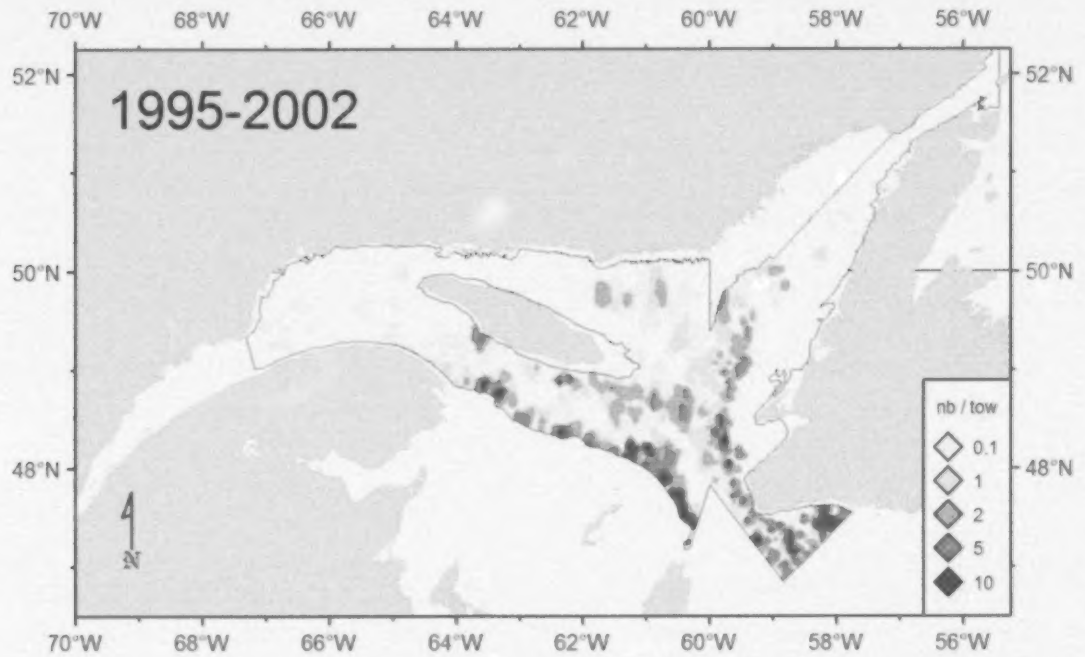


Figure 12. Geographic distribution of White Hake catches (standardized number per tow) in 3Pn4RST from the October Mobile Sentinel survey series, 1995-2002.

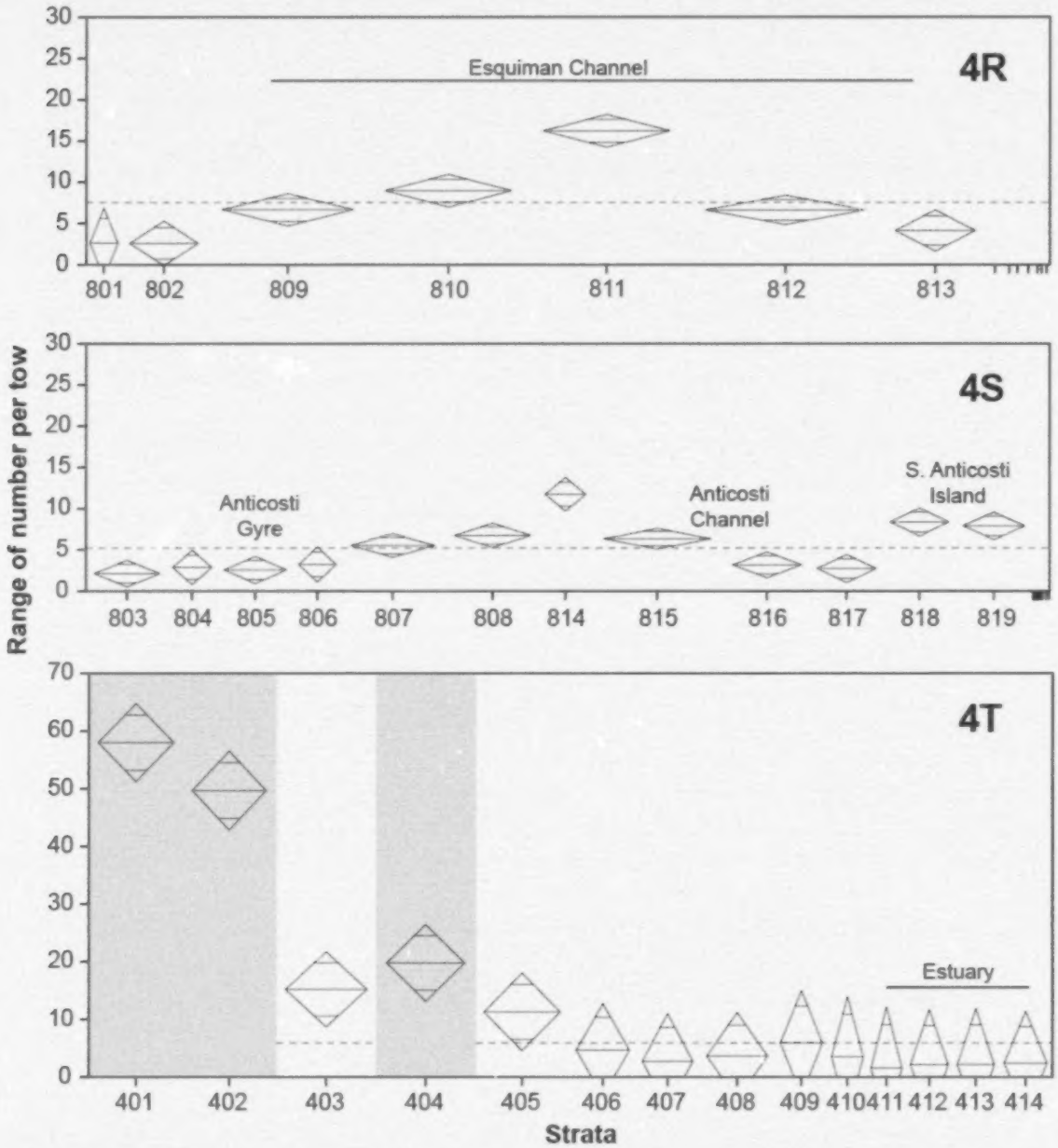


Figure 13. Distribution of White Hake catches by key strata in 4RST during the August survey series 1985-2014. Grey = excluded strata 401, 402, and 404. Diamond center line = mean number per tow by stratum, top and bottom Diamond vertices = upper and lower 95% CI. Dotted line = mean by Division. Width of diamonds proportional to number of tows performed with White Hake present. Catches are standardized number per tow (not weighted by strata area), and expressed in Lady Hammond-*Western IIA equivalent units.*

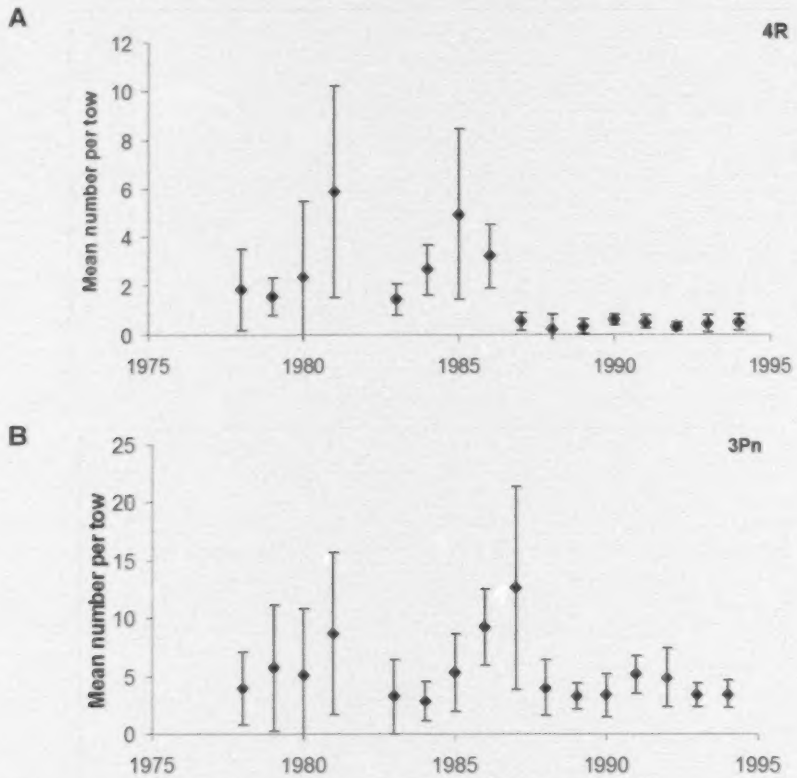


Figure 14. White Hake mean number per tow in Div. 4R (upper panel) and 3Pn (lower panel) during the Gadus-*Engel January survey series (1978-1994). Vertical lines are ± 95% CI.*

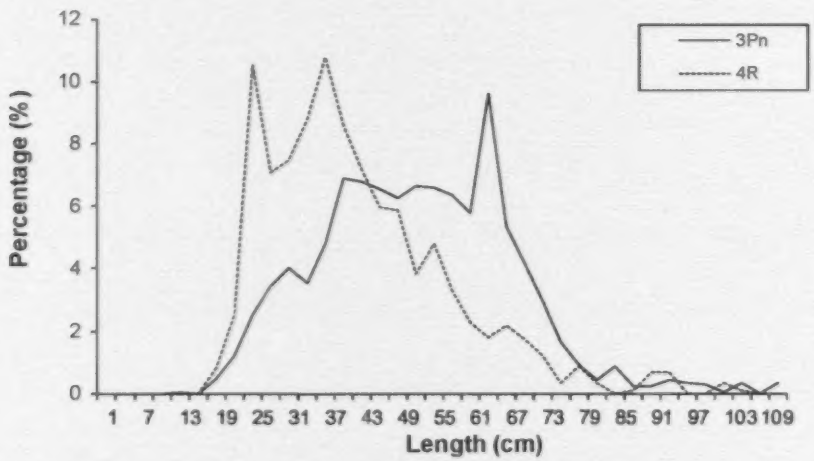


Figure 15. Size distribution of White Hake in subdivision 3Pn and Division 4R during the Gadus-*Engel January surveys for the period 1987-1994.*

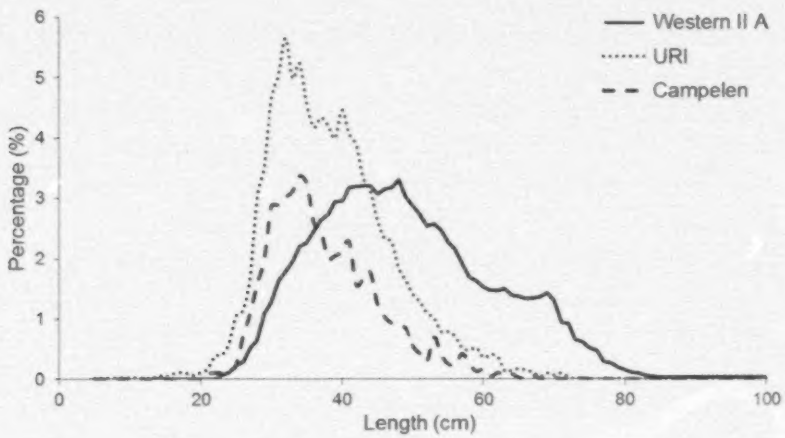


Figure 16. White Hake length distributions for the different trawls used in the August DFO RV surveys.

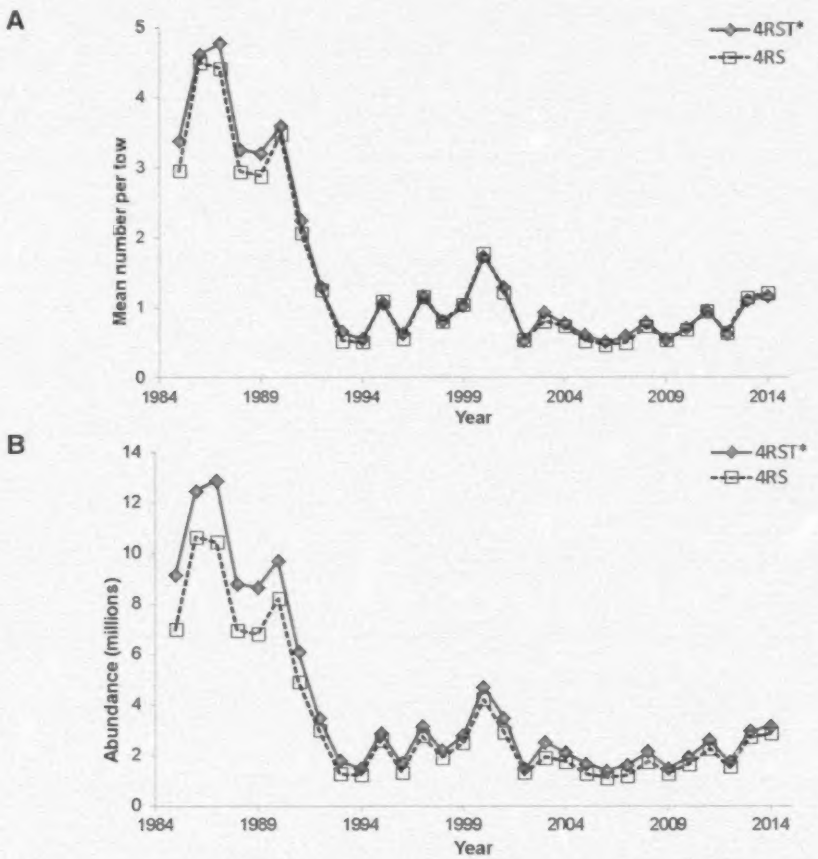


Figure 17. White Hake A) mean number per tow and B) estimated abundance (millions) from the August survey series 1985-2014, expressed in Lady Hammond-*Western IIA equivalent units. Blue diamond symbols: Div. 4RST* (excluding 401, 402, 404). Black open square symbols: Div. 4RS.*

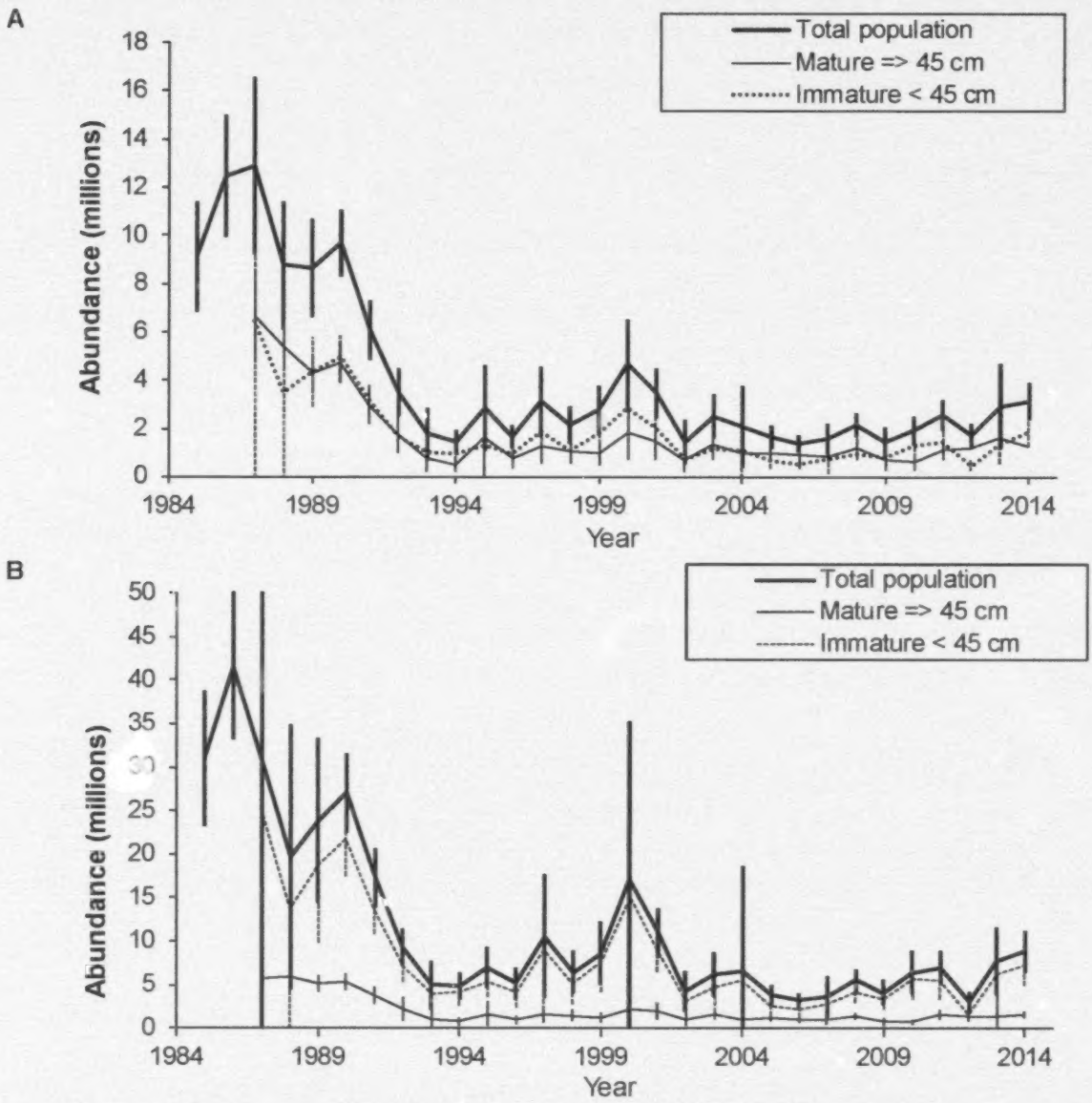


Figure 18. Minimum trawlable abundance of White Hake for total, mature, and immature size groups (immature < 45 cm, mature ≥ 45 cm) in Div. 4RST from the August surveys. A) 1985-2014 series in* Lady Hammond-*Western IIA equivalent units B) 1985-2014 series in* Teleost-*Campelen equivalent units. Vertical lines are ± 95% CI.*

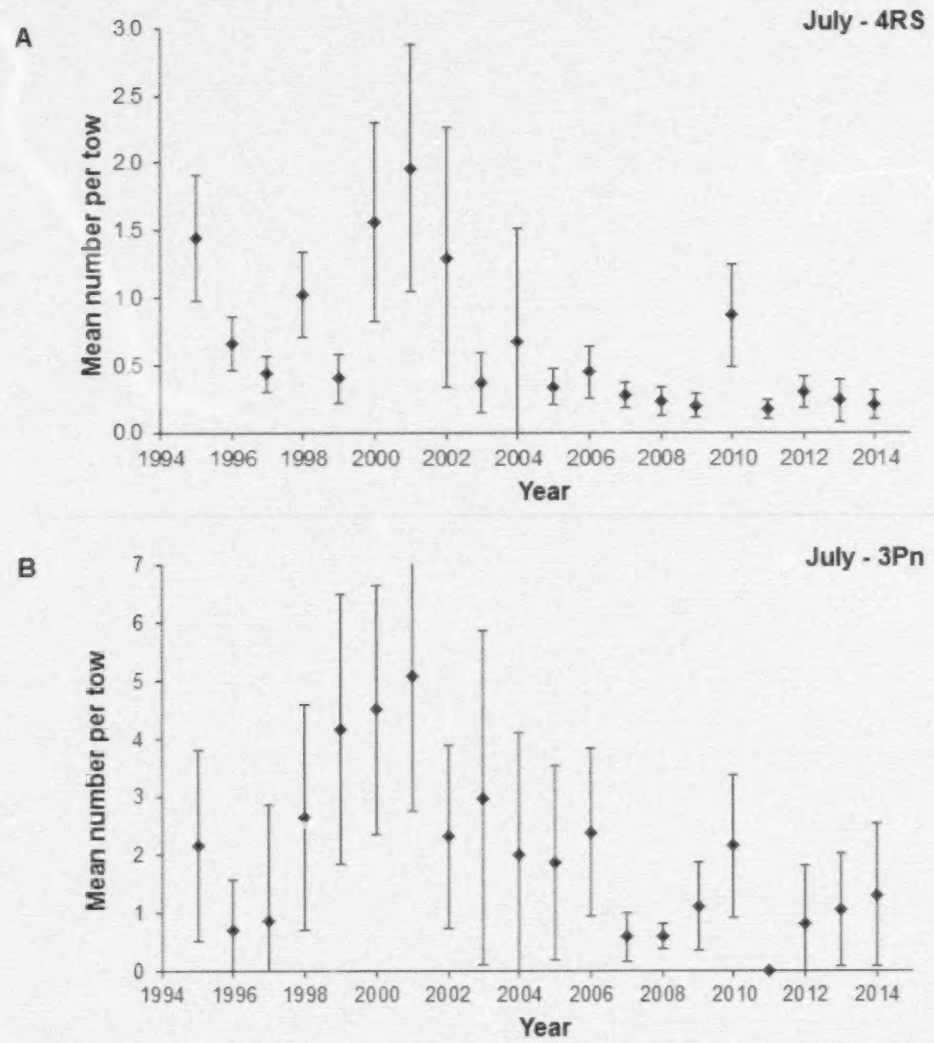


Figure 19. White Hake mean number per tow during the July Sentinel mobile survey (1995-2014) for A) Div. 4RS, and B) Subdiv. 3Pn. Vertical lines are ± 95% CI.

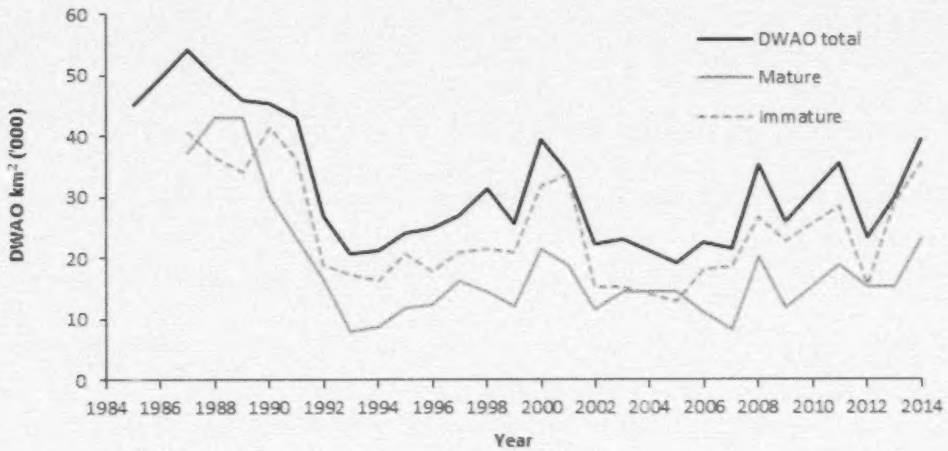


Figure 20. Design-Weighted Area Occupied (DWAO, km^2) by total, mature, and immature size groups of White Hake based on the August survey series in Divisions 4RST.*

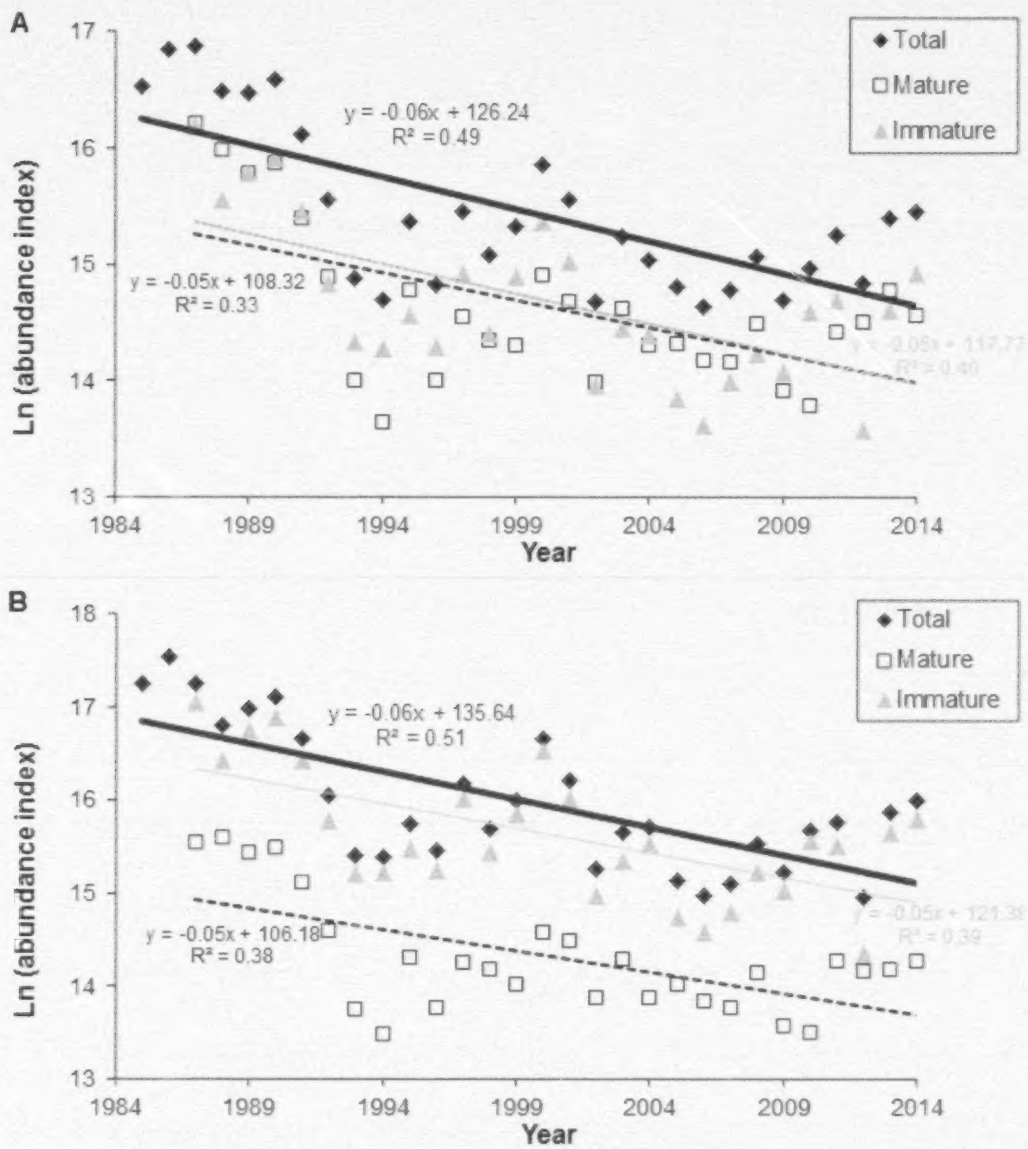


Figure 21. Trends in log-transformed abundance and their linear regression for the total, mature (≥ 45 cm) and immature (< 45 cm) size groups of White Hake in Div. 4RST on the August surveys. A) 1985-2014* Lady Hammond-*Western IIA equivalent units B) 1985-2014* Teleost-*Campelen equivalent units.*

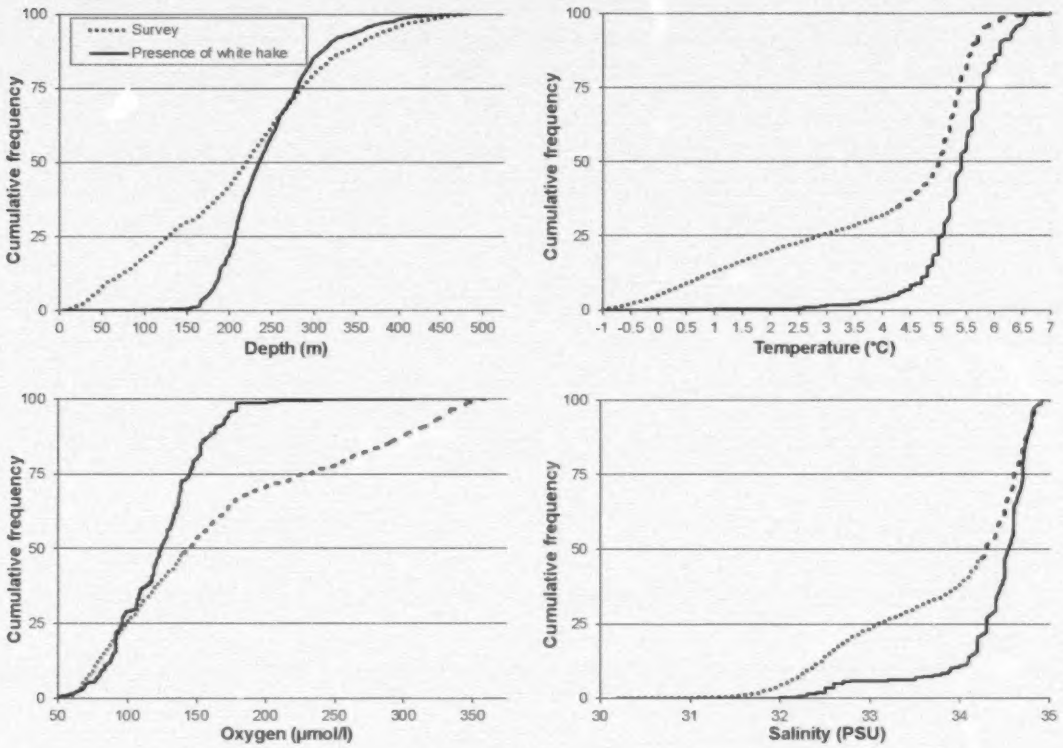


Figure 22. Cumulative frequency plots of White Hake catches and all tows according to depth, temperature, oxygen and salinity in the August survey series.

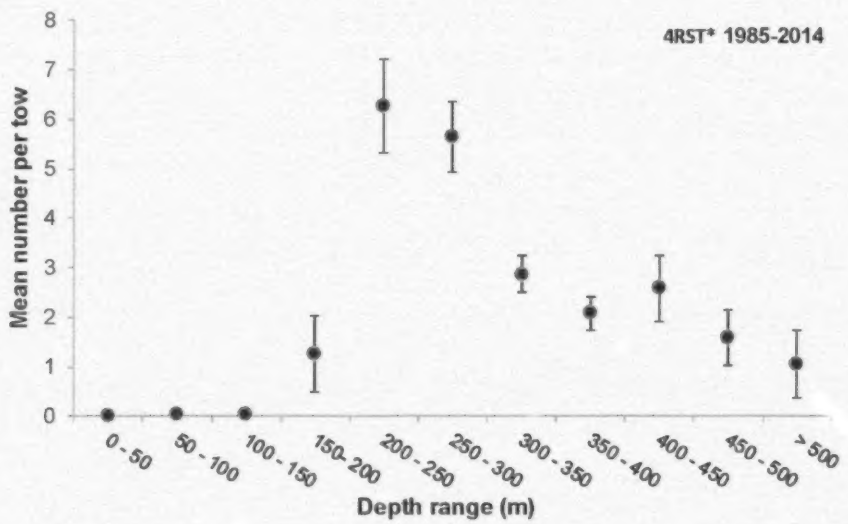


Figure 23. White Hake mean number per tow (± 95% CI) by depth classes in the August survey Teleost – *Campelen equivalent series.*

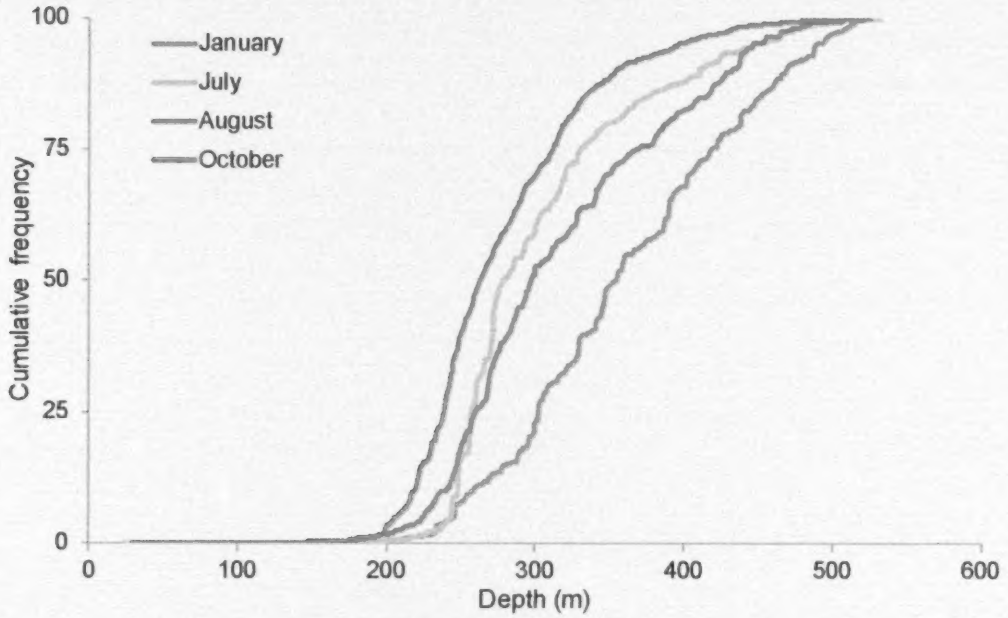


Figure 24. White Hake depth class cumulative distributions from surveys by season (January, July, August, October).

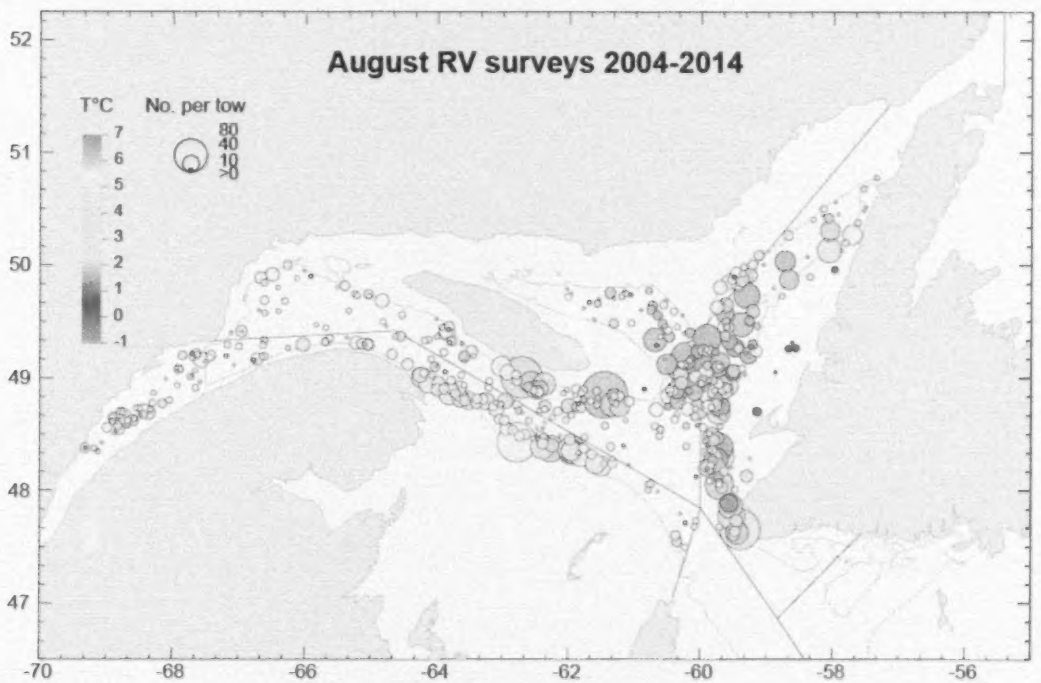


Figure 25. Near-bottom temperatures for White Hake catches on the August surveys in Div. 4RST from 2004-2014. Bubble size is proportional to abundance of White Hake (number per tow).*

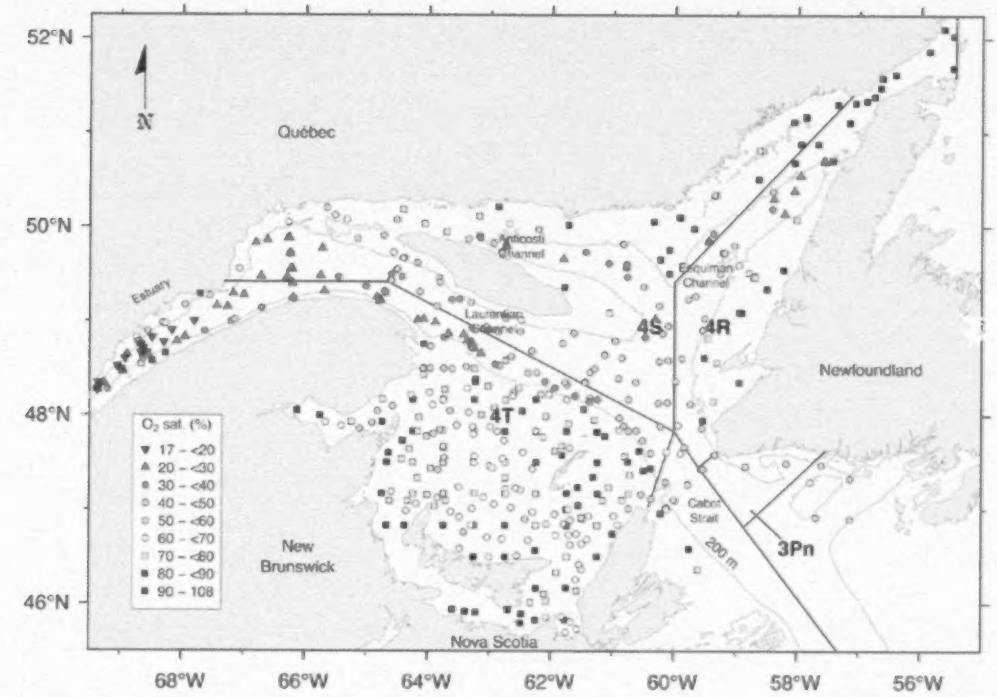


Figure 26. Near-bottom oxygen saturation from survey stations in the Gulf of St. Lawrence in 2012 (source: D. Chabot,DFO, unpublished data).

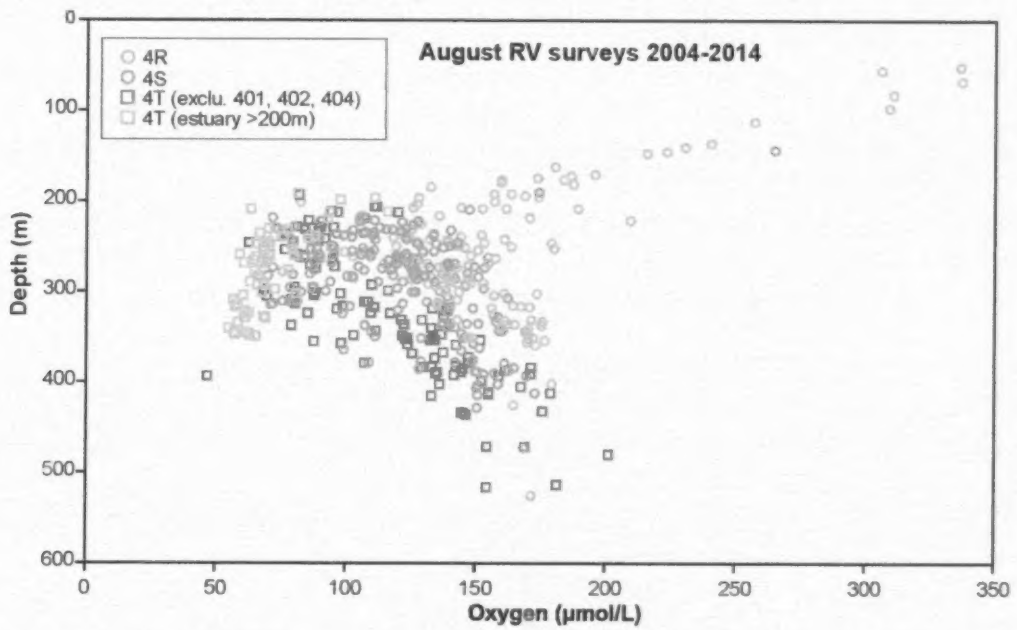


Figure 27. Occurrence of White Hake by depth and oxygen concentration from August surveys 2004-2014. Coloured by Division: orange = 4R, red = 4S, blue = 4T (401, 402 and 404 excluded), green= 4T Estuary.

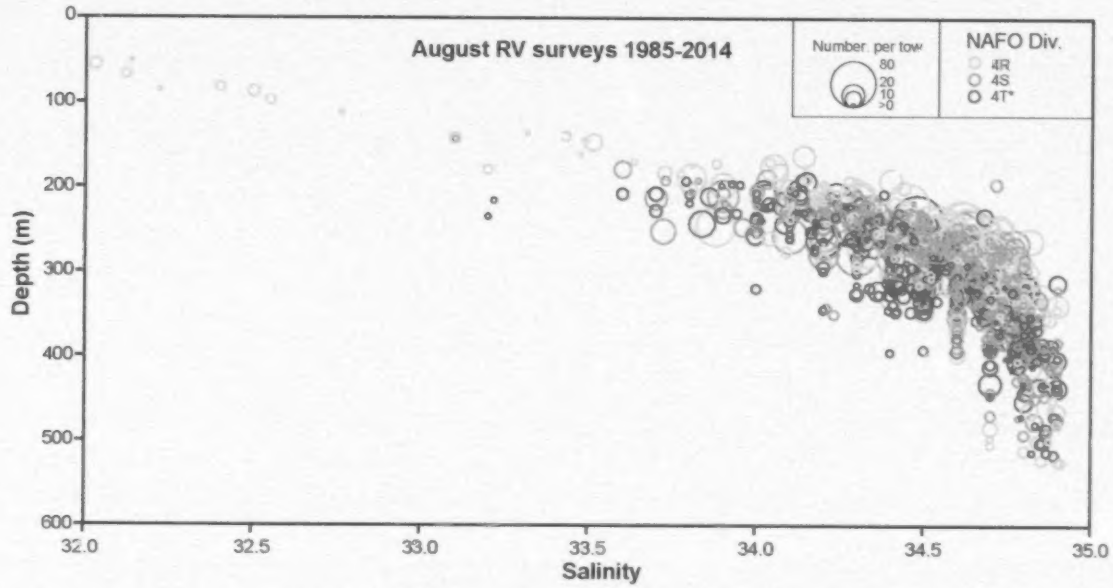


Figure 28. White Hake catches by depth and salinity in the August survey series, 1985-2014, expressed in Lady Hammond-Western IIA equivalent. Bubbles are coloured by Div. 4RST, and proportional to number per tow.*

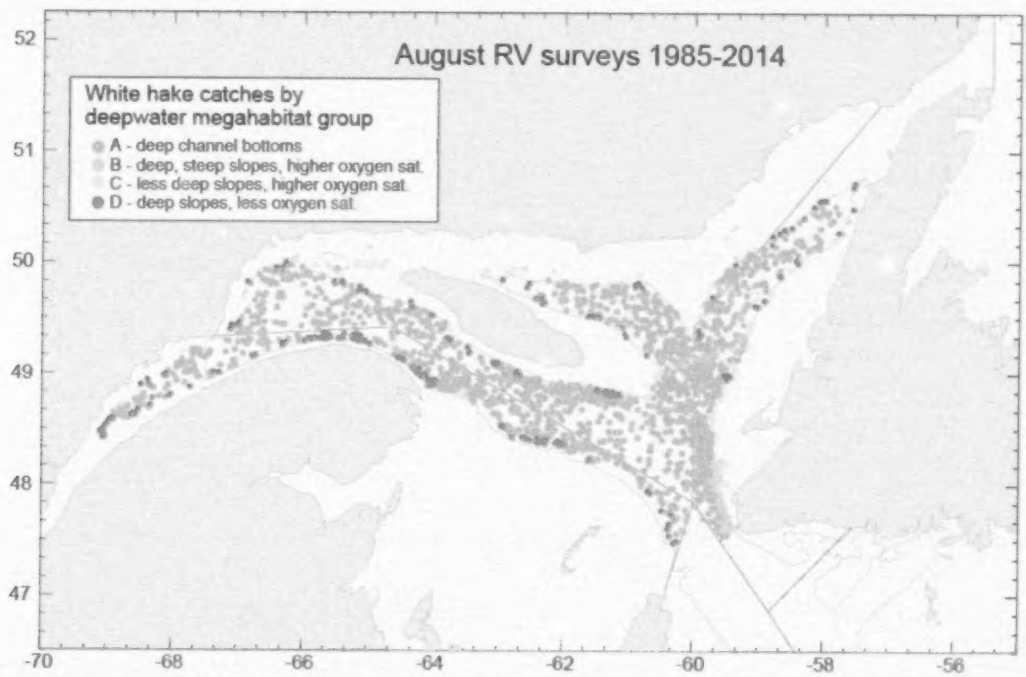


Figure 29. White Hake catches on August surveys 1985-2014 colour-coded by deepwater megahabitat groups from the St. Lawrence habitat classification atlas (Dutil et al. 2011). Symbols show presence of hake and not relative abundance.

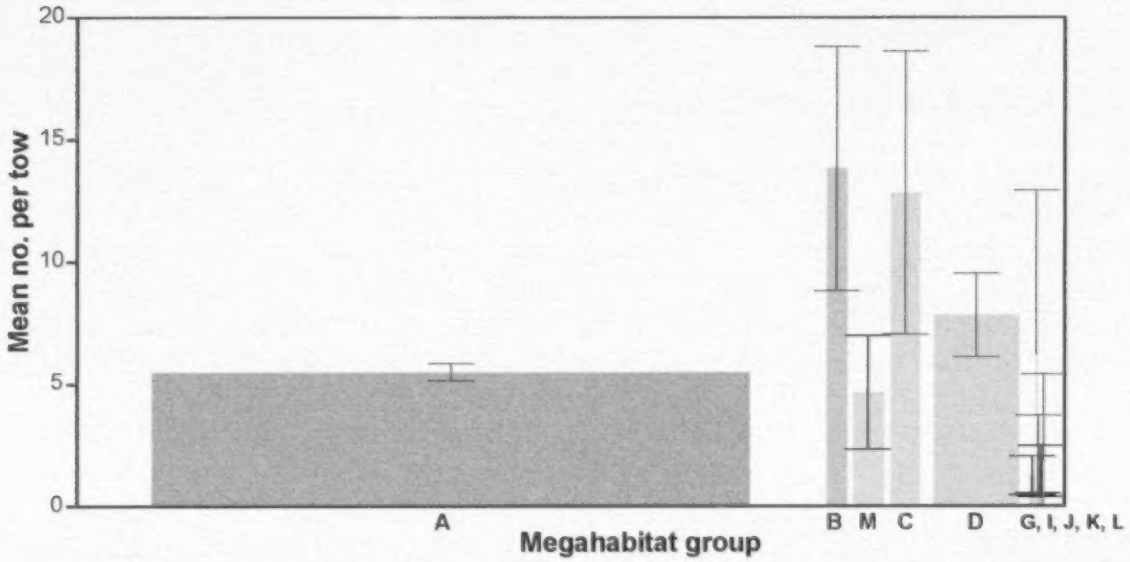


Figure 30. Relative use of habitats by White Hake from the August survey series in Div. 4RST from 1985-2014. Bar height indicates mean number of White Hake per individual tow by megahabitat group (letters). Bar width proportional to number of tows with White Hake present.*

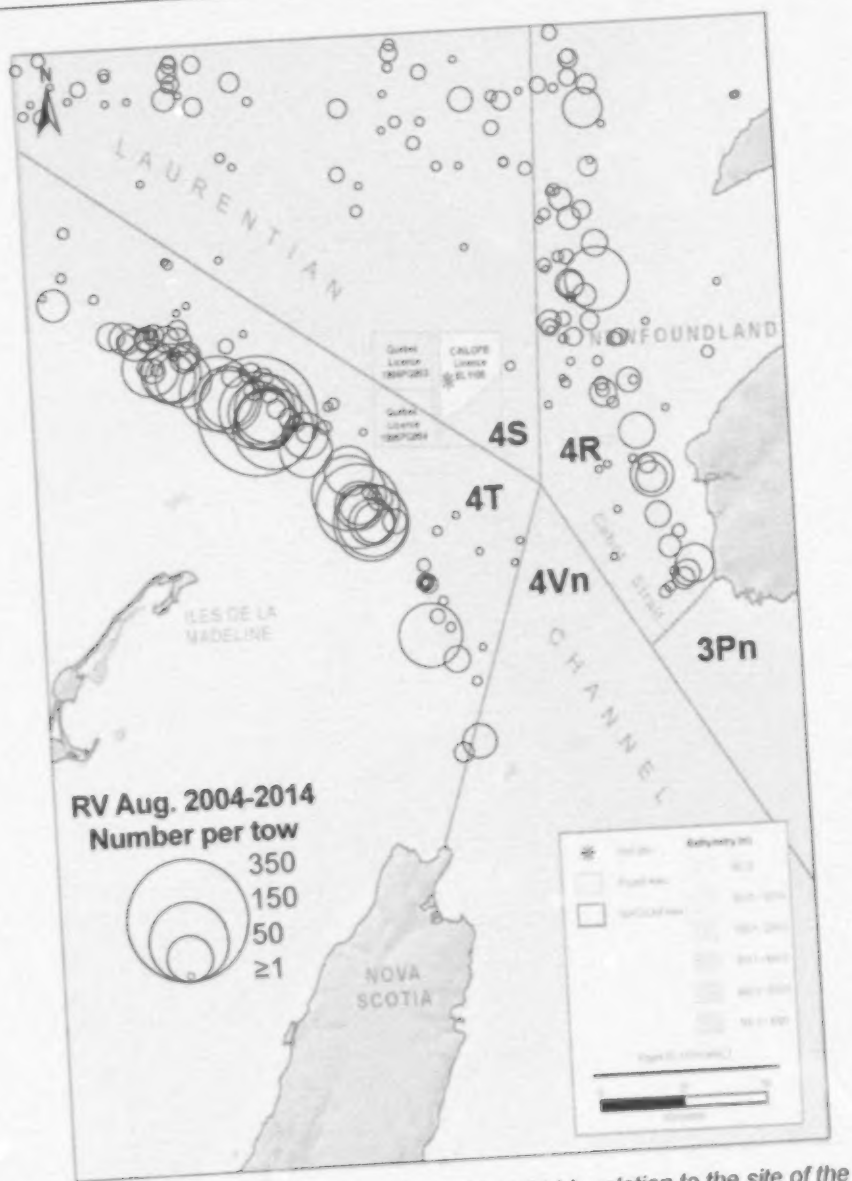


Figure 31. White Hake catches from August surveys 2004-2014 in relation to the site of the project area and exploration well for the Old Harry oil field in the Laurentian Channel of the Gulf of St. Lawrence (Source: Corridor Resources 2011). NAFO Divisions labelled in bold. Circles are proportional to number of White Hake per tow.

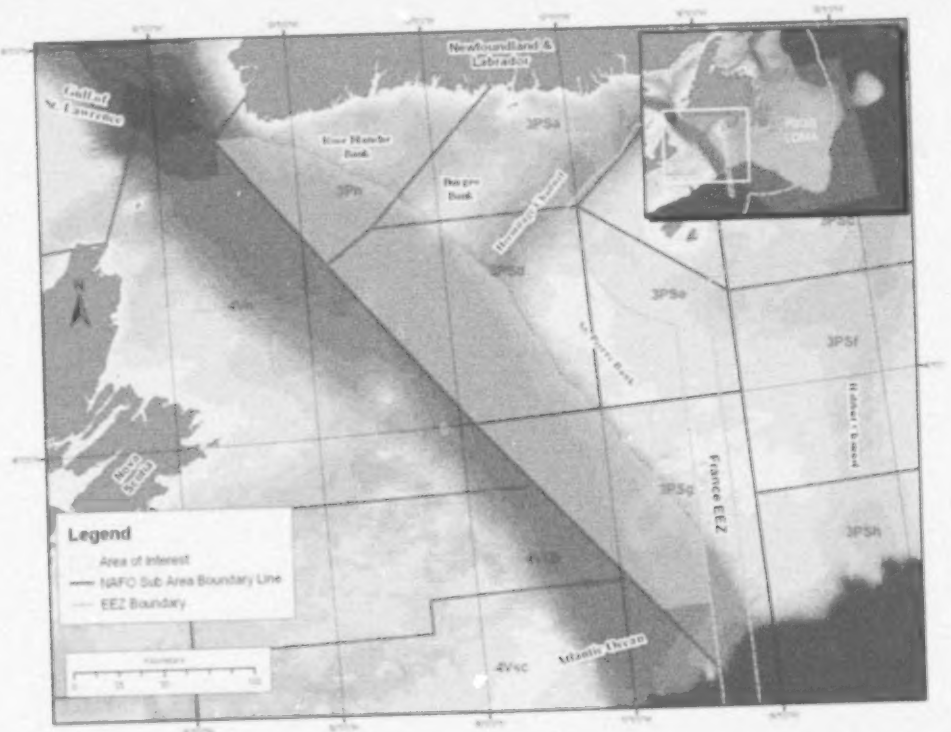


Figure 32. Laurentian Channel Area of Interest (green polygon) as a potential connectivity corridor for White Hake in the northern Gulf of St. Lawrence (DFO 2011).

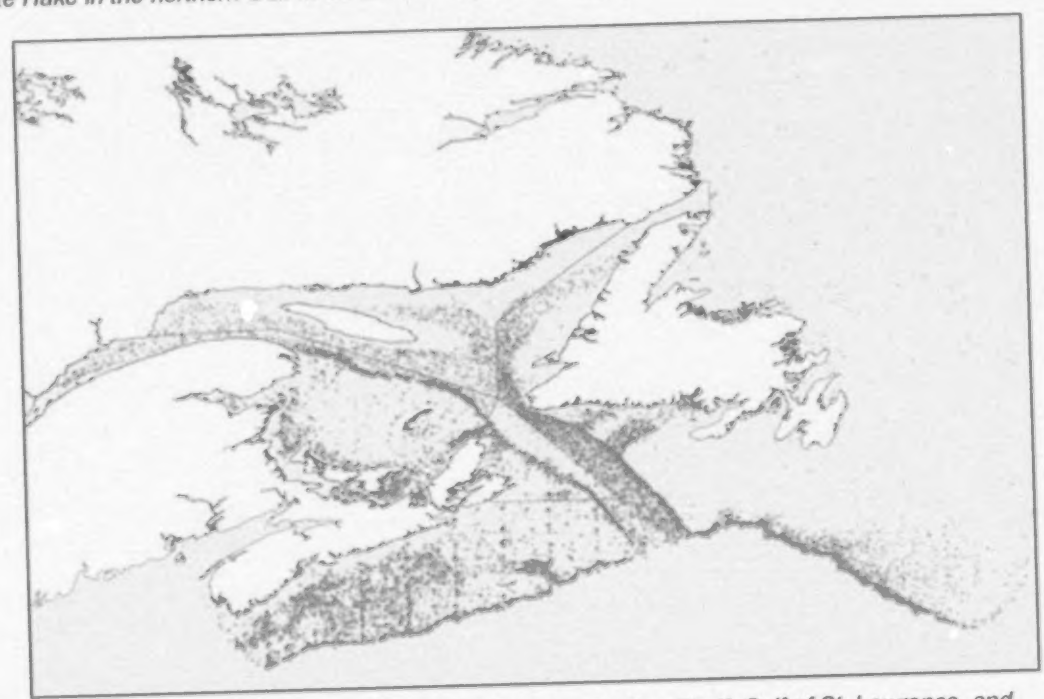


Figure 33. General occurrence records of White Hake for Scotian Shelf, Gulf of St. Lawrence, and Newfoundland areas published on the OBIS data portal (consulted 2014-10-07).

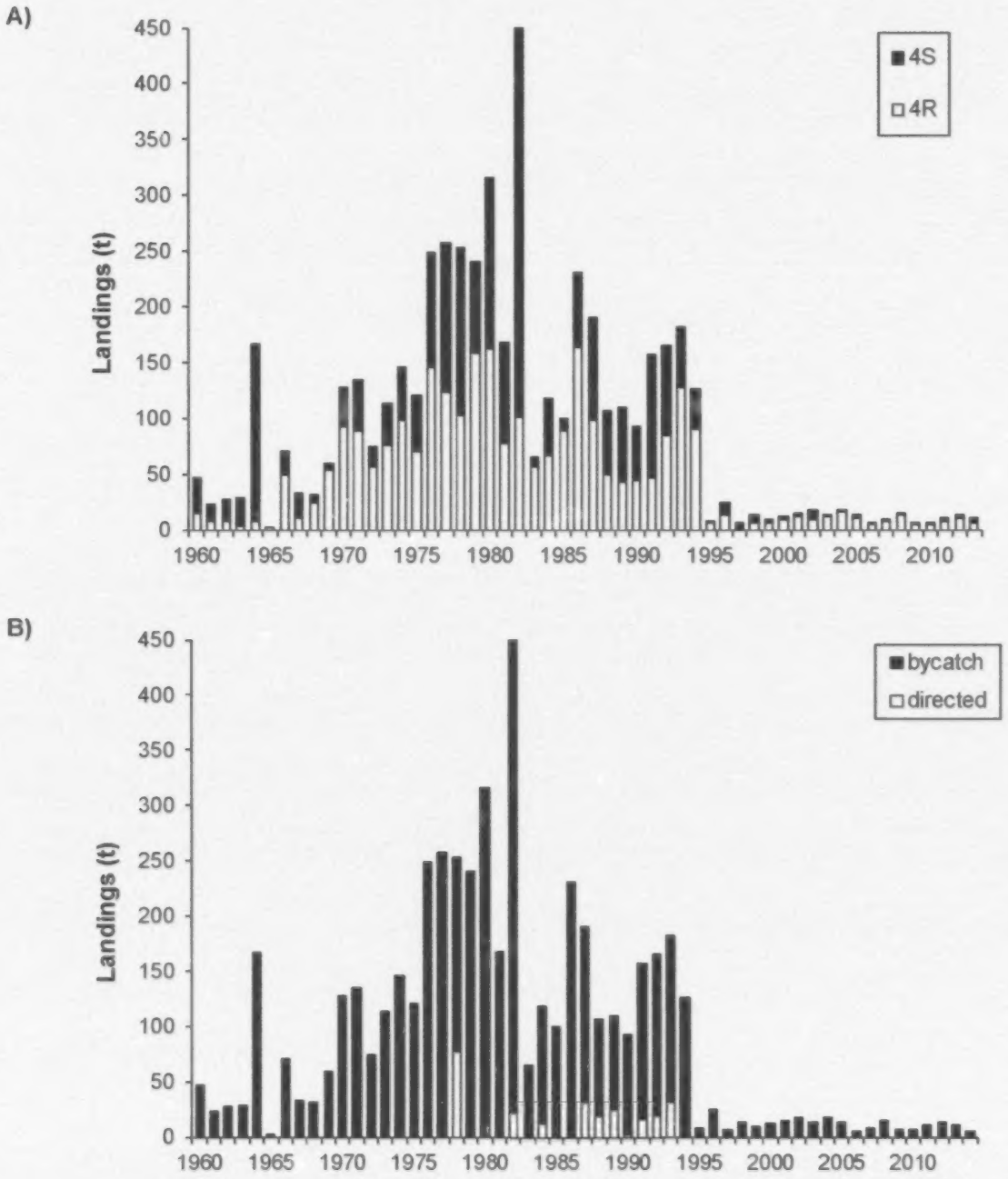


Figure 34. A) White Hake annual landings (t) divided by A) NAFO Divisions and B) directed fishery or bycatch in other fisheries. Preliminary data for 2013 and 2014.

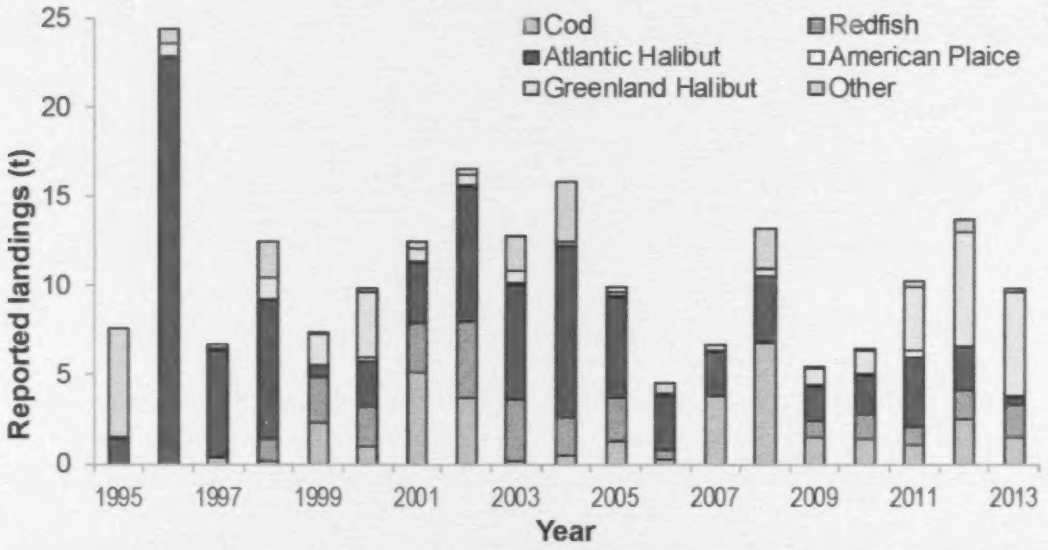
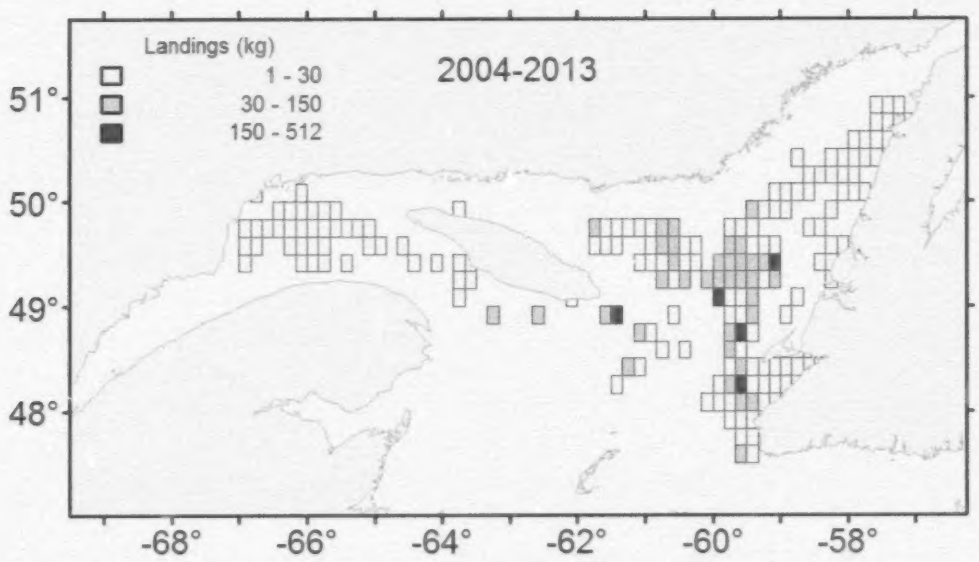


Figure 35. Reported landings of White Hake as bycatch in other fisheries in NAFO Divs. 4R and 4S.

A)



B)

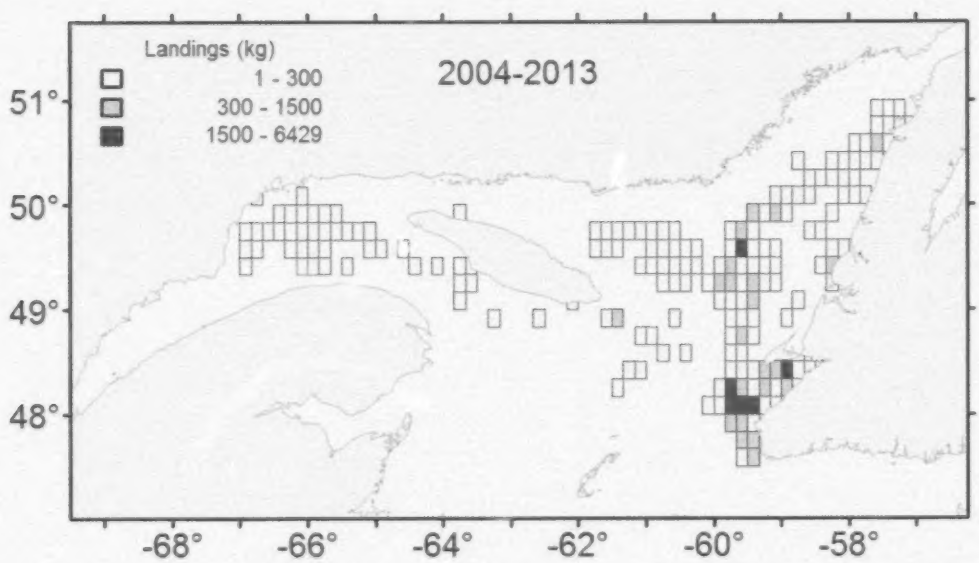


Figure 36. Locations of White Hake bycatch in groundfish directed fisheries by fishing grid in Division 4RS (partial data: the proportion of catches that are geo-referenced averaged 42% for the time period), A) mean catches per grid B) sum of catches pre grid for the time period 2004-2013.

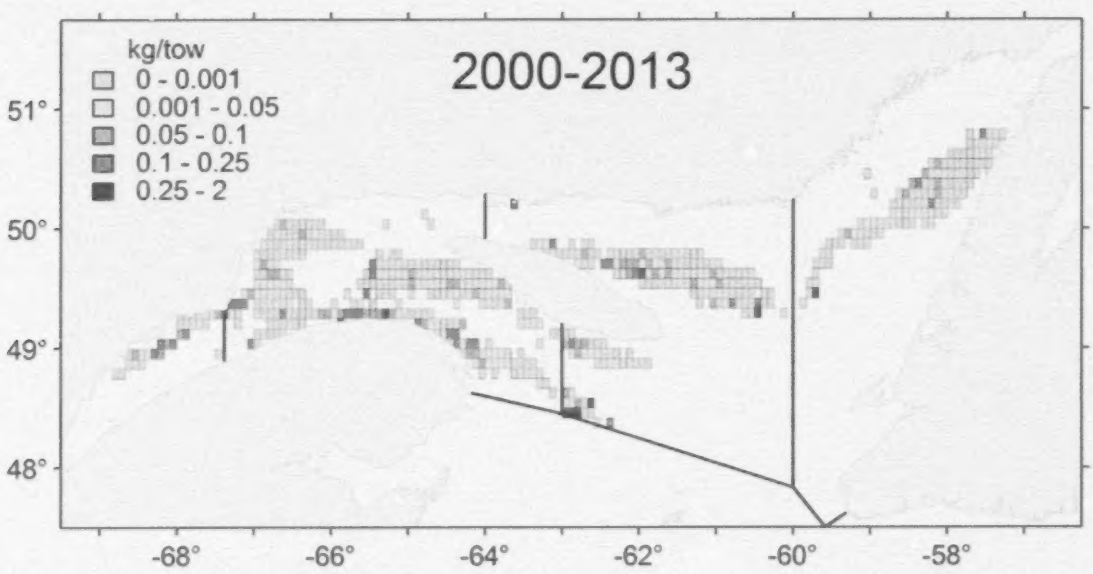


Figure 37. Geographical distribution of White Hake bycatch in the shrimp fishery in the Gulf of St. Lawrence for NAFO Divisions 4RST. White Hake catches are expressed as mean weight per tow by statistical square for the period 2000-2013.

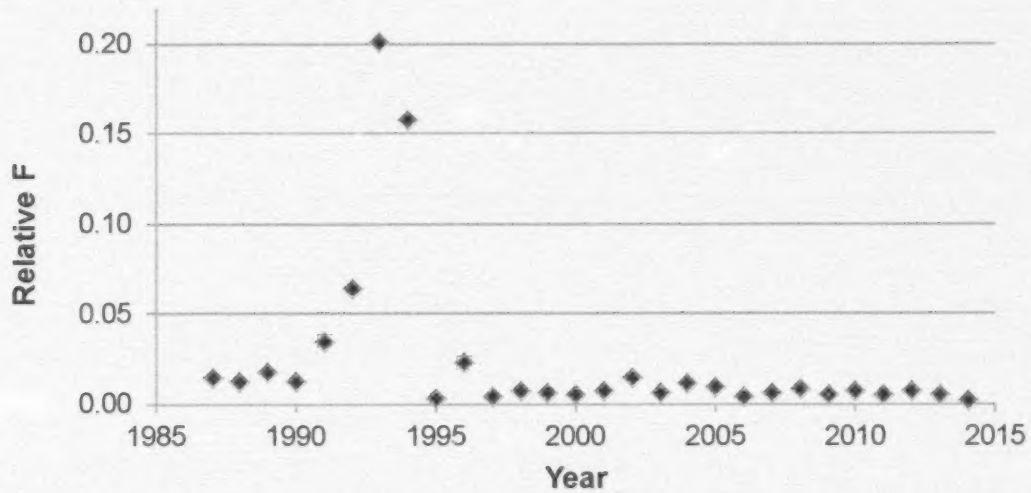


*Figure 38. Relative F estimated by the ratio of reported landings of White Hake over the estimated minimum trawlable biomass (*Teleost-Campelen equivalent units*) of mature population derived from the nGSL DFO RV survey.*

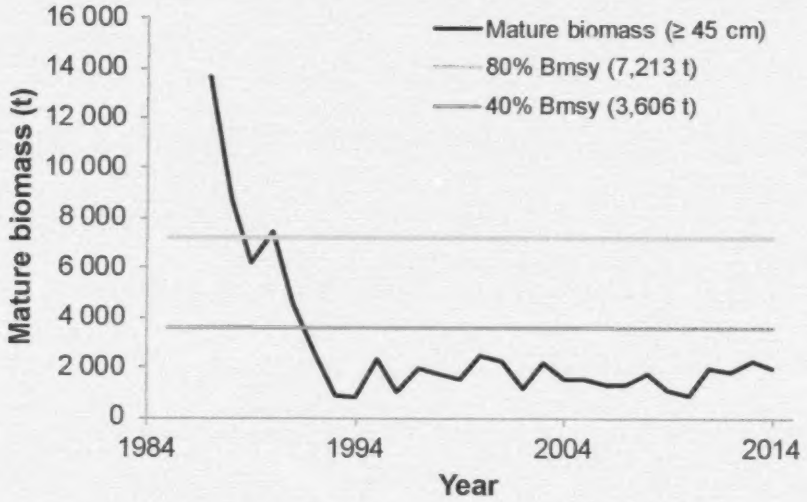
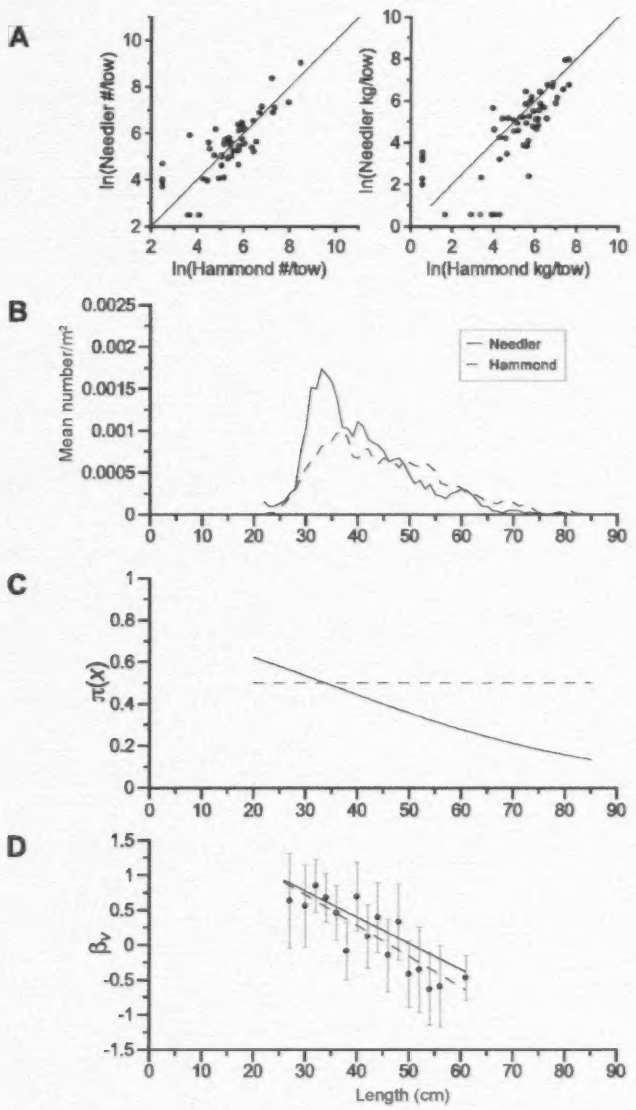


Figure 39. White Hake annual minimum trawlable mature biomass relative to the proposed abundance recovery target set at 40%Bmsy in Divisions 4RS. The candidate upper stock reference corresponding to 80% Bmsy is also shown.

APPRENDIX

Appendix 1 *Comparative fishing experiment conducted in 1990 between the Lady Hammond-Western IIA and the Alfred Needler-URI vessel trawl tandem.*



A) Catches from the CCGS Alfred Needler in relation to catches from Lady Hammond for paired comparative tows. Catches are expressed on a $\log_e$ scale; a constant equal to half of the smallest catch different from zero was added to the catches. Left panel: catch expressed in numbers per standard tow; Right panel: catch expressed in kg per standard tow. B) Total mean number of individuals caught by the CCGS Alfred Needler (full line) and by the Lady Hammond (dotted line) per size class. C) Logistic curve describing the difference in catchability (π) between the CCGS Alfred Needler and the Lady Hammond by size class. The dotted line at $\pi = 0.5$ means that the catchability is equal between tandems. D) Difference in catchability between the CCGS Alfred Needler and the Lady Hammond expressed by the vessel term of the logistic model (β_v) with its standard error, per size class. The dotted line represents the linear regression and the full line represents the exponential curve were used to model the data.